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MLS and DME/P Multipath Simulation Model User's Manual

Volume I - Operating Instructions

February 1992

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16. Abstract

This is Volume I of the MLS and DME/P Multipath Simulation Model User's Manual. The complete user's manual consists of three volumes as follows:

Volume I - Operating Instructions
Volume II - Propagation Model Theory
Volume III - System Model Theory

This volume includes descriptions of the model, both general and detailed; discussion of the input parameters and creation of the input file; instructions for operating each program of the model; discussion of the various options available for a given simulation; and descriptions of the output tables, plots, and files produced by each program. A sample input file and a set of the resulting output plots and tables are included.

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EXECUTIVE SUMMARY

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1. INTRODUCTION.

1.1 PURPOSE AND SCOPE.

The Microwave Landing System (MLS) mathematical model is a computer simulation to determine the multipath effects of an airport environment on the MLS and precision distance measuring equipment (DME/P) signals. The term multipath describes the reflection, diffraction, and shadowing phenomena that result from the various paths which exist for signal propagation from transmitter to receiver. Sources of multipath interference found in a typical airport environment are illustrated in figure 1. The simulation models the azimuth signal, the elevation signal, and the range signal (DME/P). The out-of-coverage signals are not modeled.

1.2 DOCUMENT SUMMARY.

The User's Manual for the MLS mathematical model is divided into three volumes. All volumes assume that the reader is familiar with the operating principles of MLS and DME/P (see Redlien and Kelly, 1981, on MLS, and Kelly and Cusick on DME/P). They also assume familiarity with the MLS mathematical model installation manual (Jones, 1987). This volume (Volume I) is designed to aid the user in developing the data required for modeling, in entering these data, and in running the programs to calculate and display the model results. Specifically it provides:

a. A discussion of the computer system configuration necessary to run the model.

b. A brief historical review of the model's development.

c. A model overview giving a general description of the programs included in the simulation, their functions, and their input and output.

d. A discussion of the principal features of the model.

e. A description of the data used as input to the model and the format of the input file containing these data. The input file template and an example scenario are presented.

f. An execution guide for running the model programs.

g. A description of the output data and sample output from the example scenario.

h. A discussion of information, warning, and termination messages.

i. Bibliography of related technical reports.

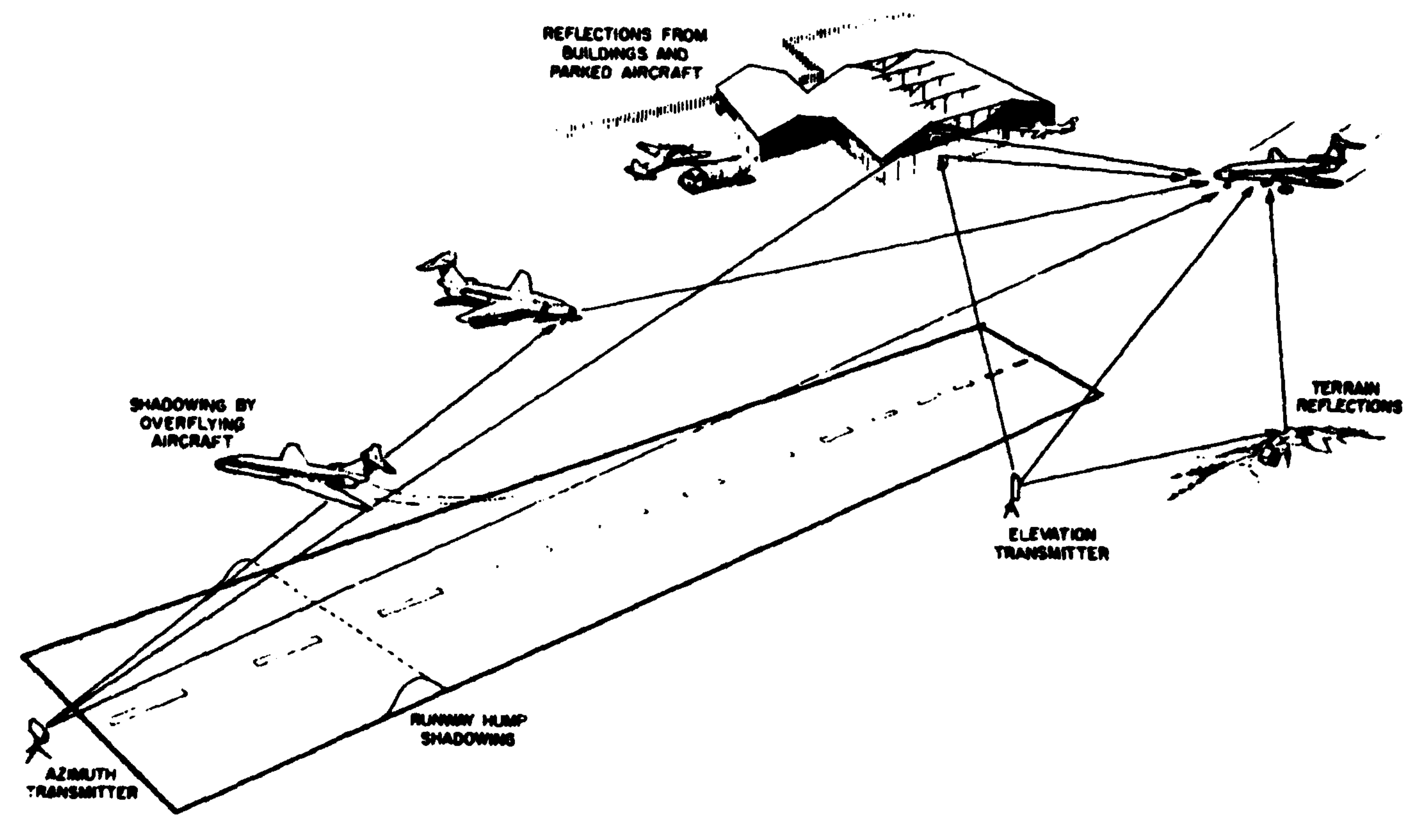

FIGURE 1. SOURCES OF MULTIPATH PROPAGATION

1.3 COMPUTER REQUIREMENTS.

The complete model consists of four computer programs. The flow diagram in figure 2 shows the relationships among these four programs. The source code, about 40,000 lines, is written in ANSI standard FORTRAN-77 and has been successfully implemented on a variety of mainframe and personal computers. The model is distributed to users as source code and must be installed and compiled by the user on his/her system.

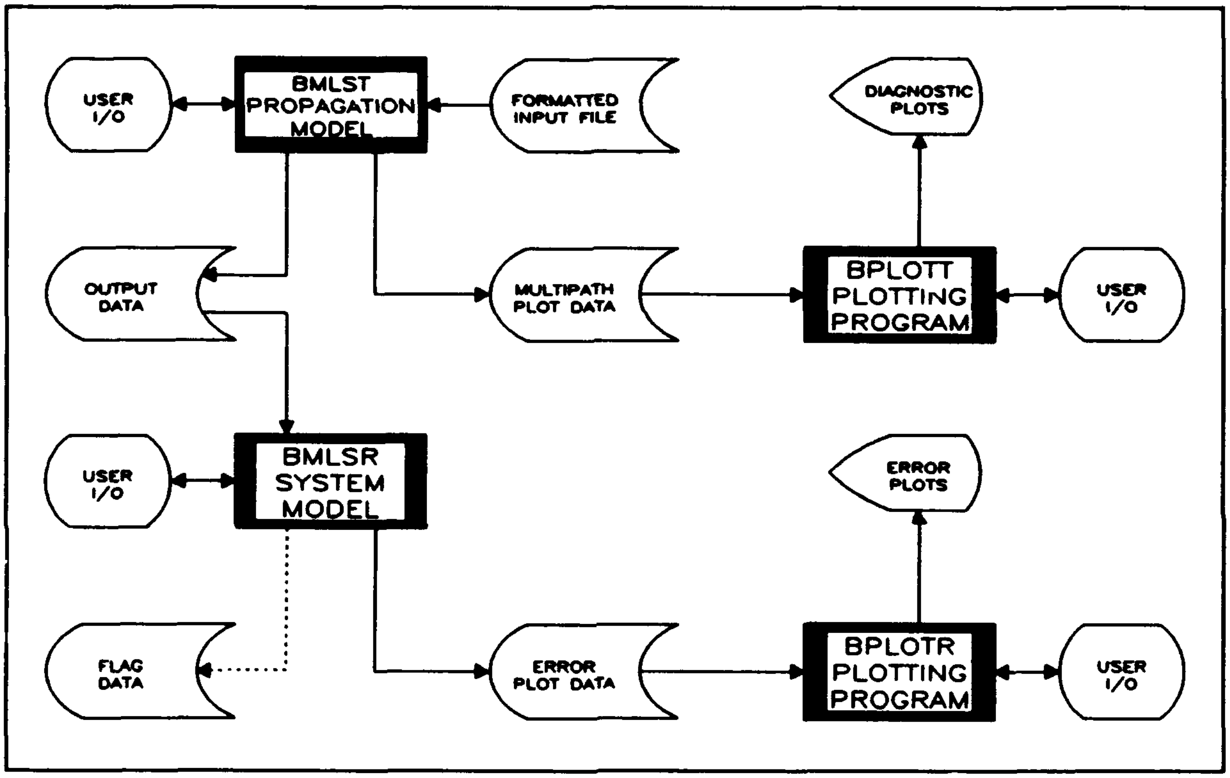

FIGURE 2. MLS MATHEMATICAL MODEL FLOW DIAGRAM

Computer system requirements include a FORTRAN-77 compiler that accepts ANSI standard source code and disk space to hold source code, executable code, and input and output files. On a personal computer (PC), at least 640K of RAM, a 20 megabyte (minimum) hard disk drive, and a math coprocessor are strongly recommended. At least one high density floppy disk drive (5.25 or 3.5 inches) is necessary for source code installation on the PC. On a mainframe, at least one tape drive that accepts 1600 bits per inch (bpi) density is necessary for installation of the source code. The model system also requires plotting devices for graphic output and user supplied subroutines to interface with these devices. The required subroutines are discussed in the installation manual (Jones, 1987). Examples of these subroutines are distributed with the model source code.

1.4 MODEL HISTORY.

The MLS mathematical model was developed at the Lincoln Laboratory of the Massachusetts Institute of Technology (MIT) under contract with the Federal Aviation Administration (FAA). The original purpose of the model was to compare the performance of different types of MLS technologies (i.e., Doppler systems and time reference scanning beam (TRSB) systems) in the same airport environment. The model as delivered to the FAA Technical Center in 1981 was modified to simulate only TRSB, the standard chosen by the International Civil Aviation Organization (ICAO) in 1978. The FAA Technical Center subsequently converted the model to FORTRAN-77, modified it to be portable to different computer systems, and distributed the source code to users around the world. The model has proven to be a valuable tool in the analysis of multipath interference from an airport environment on the MLS and DME/P signals.

Resistance to multipath interference is a key technical issue in assessing both the relative and absolute capabilities of various landing systems. Results of analyses in the national MLS program, as well as the results of a comprehensive study conducted for the North Atlantic Treaty Organization Industrial Advisory Group (NIAG), suggest that large aircraft and/or vertical structures near the approach zone might be major sources of error. The continuing construction of buildings near approach and landing zones, and the increasing use of wide body aircraft, both potentially significant multipath sources, increase the possibility of multipath effects on the landing guidance system. System type and site geometry are additional issues in the avoidance of multipath interference on the MLS. Computer simulation is the most practical technique available to evaluate the performance of the MLS in a specific airport environment. Models can be used to examine the sensitivity of the system to important airport features both existent and proposed. This, in turn, leads to a much better understanding of the strengths and deficiencies of the MLS in a complicated airport environment. There are several factors which make computer simulation a desirable method for evaluating system multipath performance:

a. It allows for convenient evaluation of MLS and DME/P performance under a variety of airport and flightpath conditions.

b. It reduces the substantial expense and precision instrumentation associated with quantitatively meaningful field tests.

c. It permits the investigation of the system sensitivity to multipath parameters for a variety of site locations.

d. It enables one to evaluate performance for anticipated airport environments (i.e., with more and/or larger buildings than now exist).

The MLS mathematical model, which specifically addresses issues of system type and site geometry, is used as a tool in evaluating the TRSB system in various site locations at specific airports prior to installation, and in anticipating performance, after installation, when construction or other factors change the airport environment.

1.5 OVERVIEW OF MODEL.

The MLS mathematical model consists of four separate programs (see figure 2): BMLST and the plotting program BPLOTT, BMLSR and the plotting program BPLOTR. A complete site simulation is performed in two stages: execution of the propagation (or transmitter) model and execution of the system (or receiver) model.

1.5.1 Description of the Propagation Model.

The first stage of a site simulation, program BMLST, models the behavior of the MLS transmitter and the DME/P transponder. This is referred to as the propagation model, a simulation of the signal in space as it interacts with objects in the airport environment. It assumes that all transmitting and receiving antennas have an omnidirectional radiation pattern. The numerical results from the propagation model define the direct signal, signals reflected from or diffracted by terrain, buildings, and aircraft, and the changes in the direct signal characteristics due to shadowing by runway humps, buildings, and aircraft. The type of multipath considered in a simulation is determined by the input parameters entered by the user in the input data file.

1.5.2 Types of Multipath Simulated in the Propagation Model.

a. Terrain Reflection Modeling. The model assumes the default ground to be an infinite flat plane. In addition, terrain can be represented by a collection of rectangular and triangular plates, each with user defined size, location, orientation, roughness, and dielectric constant. By varying these parameters, the sensitivity of MLS performance to terrain type (e.g., dry ground versus snow) can be assessed. Multipath levels are computed either by a numerical Kirchoff-Fresnel integral or by a simplified approximation.

b. Building Reflection Modeling. Buildings are represented by one or more rectangular plates of user defined size, location, orientation and surface material. The plates should represent features of a building such as the doors of a hangar. By allowing each plate to have a different surface material, a building consisting of a number of different homogeneous surfaces (e.g., concrete walls with metal doors) can be modeled. Consideration is also made for secondary ground reflection paths in this reflection model. Multipath levels are computed assuming Fresnel diffraction using closed form Fresnel integral expressions.

c. Aircraft Reflection Modeling. With aircraft, it is essential to consider the curvature of the surfaces as this tends to spread the reflections over a much greater region than would be the case with flat plates. The fuselages and tail fins are both modeled as cylinders or a section thereof. The resulting multipath levels are computed by a combination of Fresnel diffraction (integral) and geometric optics. The aircraft geometric characteristics are stored by aircraft type in a data library internal to the simulation program. The user specifies the aircraft type and location.

d. Shadowing. Shadowing by buildings or aircraft may cause both an attenuation and distortion of the transmitted wave front. Both of these factors are considered in the models for shadowing. The shadowing obstacles are represented by one or more rectangular plates which approximate the object silhouette. The user can specify the location of the shadowing object and, in the case of a moving aircraft, flightpath and velocity. Similar techniques have been used successfully in studying the effects of wide-body aircraft on the Instrument Landing System (ILS). Shadowing by runway humps creates problems similar to shadowing by other obstacles in that it causes both attenuation and distortion of the MLS signal. The runway hump is modeled as a circular cylinder with a radius that approximates the radius of the runway hump. The cylinder is defined by three points at the front, peak and back of the hump with the peak, or center-point, being the highest point of the cylinder in the X-Y (ground) plane.

(Note: Validation has shown the method of runway hump modeling to be less than adequate. Alternative approaches to runway hump shadowing are currently under investigation, and the model may be modified or supplemented in the future with a different methodology. Validation studies using shadowing aircraft have yielded mixed results due to the method of representing the aircraft fuselage and tail as simplified rectangular plates. This leads to significant differences between measured and modeled data when the tail fin of the shadowing aircraft falls within the line-of-sight between the transmitter and receiver. This problem is currently under investigation and will be corrected appropriately.)

Output from BMLST is written to two files. One file provides plotting information to BPLOTT, a program that plots the multipath and shadowing effects on the signal from each of the ground stations: azimuth, elevation, and DME/P uplink and from the airborne DME/P downlink interrogator. The second file is the input file to BMLSR, the second stage of simulation.

1.5.3 Graphic Output of the Propagation Model.

Both tabular and graphic outputs are produced by the propagation model plotting program. Examples are given in the appendix.

The following tabular listings are produced by the propagation plotting program BPLOTT:

a. Input parameters for a simulation run.

b. Flightpath description (except measured flightpath).

c. Relative multipath amplitudes for the azimuth, elevation, DME/P uplink, and DME/P downlink signals.

The following plots are produced by the propagation simulation through BPLOTT:

a. Map of the airport and the obstacles defined by the user.

b. Several views of the flightpath of the aircraft.

c. Ratios of the amplitudes of the multipath signals to the direct signal as a function of the aircraft position, for the azimuth, elevation, DME/P uplink, and DME/P downlink systems.

d. Separation angles (time delays for DME/P) between the multipath signals and the direct signal as a function of aircraft position, for the azimuth, elevation, DME/P uplink, and DME/P downlink systems.

e. Amplitude variation in the direct signal where shadowing is involved for the azimuth, elevation, DME/P uplink, and DME/P downlink systems.

<u>1.5.4 Description of the System Model</u>.

In the second stage of a simulation, program BMLSR models the behavior of an MLS receiver and DME/P interrogator at each point along the flightpath. Once the receiver simulation has determined an MLS angle, or range in the case of DME/P, it compares this value with the true position of the aircraft as defined by the flightpath coordinates in the input file. The angular (or range) difference between these positions is the error at that flightpath point for that system (azimuth, elevation, or DME/P). This error is written to an output file which is used by program BPLOTR to plot the error data. BPLOTR also filters the error data with both path following error (PFE) and control motion noise (CMN) algorithms and plots the filtered data with appropriate error tolerances. These plots allow the user to evaluate the receiver errors and determine if they fall within the acceptable tolerance limits.

The transmitting antenna type and the MLS receiver (or DME/P interrogator) are both simulated in the system model. The model considers the received signal as a superposition of the received direct path signal and a number of replicas (multipath) of it, each having its own amplitude, delay, and phase angle. The amplitude

for each multipath signal is extracted from the corresponding transmitting antenna pattern based on position. The system model multiplies each received signal by the appropriate antenna gain and then constructs the received envelope by superimposing the transmitted signals. The program contains a library of antenna patterns which are listed in table 1. They are either the theoretical or the measured pattern for each antenna. The airborne antennas are assumed to have an omnidirectional receiver pattern. Therefore, only the patterns of the transmitting antennas (ground equipment) need be considered.

The critical measurement made by the MLS receiver is the time of arrival of a signal. The differences between the times of arrival of the TO and FRO signals for the azimuth and elevation signals determine the azimuth angle and the elevation angle, respectively. The system model simulates either of two processing techniques to measure the time of arrival of a pulse: the dwell gate or the split gate method. Dwell gate processing finds the peaks of the TO and FRO envelopes and then finds the thresholds on the leading and trailing edges of each envelope. Split gate tracking finds the peak and adjusts it if there is an imbalance in the area under the envelope before and after the peak. In either case, checks of TO - FRO symmetry and specific tracking algorithms are applied to each measurement before being presented as angle data.

The time of arrival of the DME/P signal determines the range. The DME/P simulation uses two methods of determining the time of arrival. Method 1, the current standard, is used when the aircraft is far away, i.e., at ranges greater than 7 nautical miles (nmi). Method 2, a more precise method of thresholding, is used for ranges of less than 7 nmi. These two methods of determining the threshold parallel the en route and final approach (precision) methods of DME operation. In both cases the results are further processed to simulate reply efficiency, data falling outside an established track gate, and data lost during transponder identification transmissions.

1.5.5 Graphic Output of System Model.

Graphic output of system model data are plotted by BPLOTR. Angle errors (in degrees) and range errors (in feet) are plotted as a function of aircraft position for each system.

The following output plots are provided:

a. The error as a function of aircraft position, statically measured (no motion averaging correction).

b. The error as a function of aircraft position, dynamically measured (motion averaging correction and alpha-beta filter).

TABLE 1. TRANSMITTER ANTENNA TYPES AND PATTERNS

Azimuth Antennas

Type	Pattern	Beamwidth	Scan
AZBN	Bendix basic narrow	2°	40°
AZG1X60	Generic wide	1°	60°
AZG2X40	Generic narrow	2°	40°
AZG3X40	Generic narrow	3°	40°
AZH1X40	Hazeltine narrow	1°	40°
AZH1X60	Hazeltine wide	1°	60°
AZH2X40	Hazeltine narrow	2°	40°
AZBL1060	Bendix test bed (left half)	1°	60°
AZBR1060	Bendix test bed (right half)	1°	60°
AZBL2040	Bendix test bed (left half)	2°	40°
AZBR2040	Bendix test bed (right half)	2°	40°

Elevation Antennas

Type	Pattern	Beamwidth
ELBN	Bendix basic narrow	1.5°
ELG10C	Generic compact	1°
ELG15C	Generic compact	1.5°
ELG20C	Generic compact	2°
ELH10C	Hazeltine compact	1°
ELH15C	Hazeltine compact	1.5°
ELB15	Bendix test bed	1.5°

DME Antennas

Type	Pattern	Beamwidth
DMBN	Generic DME	Omnidirectional

c. The error, filtered by the PFE (low pass) filter, as a function of aircraft position.

d. The error, filtered by the CMN (high pass) filter, as a function of aircraft position.

2. PRINCIPAL FEATURES OF THE MATHEMATICAL MODEL.

The main source of errors in the MLS is the multipath propagation of signals. Multipath, which can be severe close to the ground, distorts the signals received by the aircraft. As a result, the azimuth, elevation, and range measurements may be in error. The multipath effects are modeled by the simulation program; in addition, thermal noise and reply efficiency (other sources of error) are modeled for the DME/P.

The model has two principal parts: the signal-in-space or propagation model, and the signal processing or system (receiver) model.

The propagation model simulates the position of the aircraft and calculates the amplitude level of the azimuth, elevation, and DME/P signals at that position. This part of the model assumes an omnidirectional antenna radiation pattern.

The system model simulates the processing of the received multipath signals by the airborne equipment. The processing produces estimates of the current azimuth angle, elevation angle, and range of the aircraft from the azimuth, elevation, and DME/P ground stations, respectively. This estimated position of the aircraft is compared to the true position which is known to the simulation. The differences between these two positions generate the MLS errors estimated by the model.

The signal at the aircraft is the superposition (amplitude and phase) of the following multipath signal components:

a. Direct signal

b. Specular scattering from the ground

c. Diffuse scattering from the ground

d. Scattering from buildings

e. Scattering from aircraft

f. Shadowing by buildings

g. Shadowing by aircraft

h. Shadowing by runway hump

The components b through h are caused by obstacles. An obstacle is a natural or man-made feature of the local environment, which interferes with the propagation of the electromagnetic signal from the transmitter to the receiver. The model incorporates three kinds of obstacles: buildings, aircraft, and ground. An obstacle

such as a truck which has the interference characteristics of a building can be modeled as a building.

The errors caused by a multipath signal depend on the following characteristics:

a. The multipath signal level relative to the direct signal level.

b. The angular difference between the direction of propagation of the multipath signal from the transmitting antenna and the direction of propagation of the direct signal from the transmitting antenna (the separation angle).

c. The multipath path delay (which causes a phase difference between the direct and multipath signals).

d. The rate of change of path delay.

2.1 PROPAGATION MODEL.

The model is basically a ray tracing model although both physical and geometric optics algorithms are used. The signal-in-space is the sum (amplitude and phase) of signal components from all of the significant propagation paths.

Complex real world objects are represented by simpler objects which more readily lend themselves to practical computation routines. Flat plates, either rectangular or triangular, are used to model the ground and buildings; cylinders are used to model aircraft and a runway hump.

The computation of the effect of shadowing by any obstacle includes specular ground reflection. Consequently, the independent specular ground reflection calculation is omitted when there is a shadowing calculation. Also, the model does not permit simultaneous shadowing by a building and a runway hump or by an aircraft and a runway hump. Simultaneous shadowing by buildings and aircraft is allowed by the model.

2.1.1 Ground Reflections.

The propagation model can produce both specular and diffuse ground reflections for the MLS and DME/P signals.

Specular (mirror-like) reflection is highly directional, and its phase is coherent, that is, the phase of the reflected wave is directly related to the phase of the incident wave. In addition, specular reflection results from radiation from an area within the first few Fresnel ellipses or zones.

Diffuse scattering from the ground has less directivity and takes place due to radiation from the glistening surface which is much larger than the first few Fresnel zones. Both the amplitude and the phase are described as random variables. The amplitude has a Rayleigh distribution, and the phase has a uniform distribution.

In general, both specular and diffuse components are present simultaneously. If the root mean square (rms) roughness height is small compared to the wavelength, the specular component predominates. Otherwise, the specular component is negligible, and the diffuse component predominates.

2.1.1.1 Specular Ground Reflections.

Specular ground is represented as a set of one or more flat plates, either rectangular or triangular. Each plate is characterized by a geometric position and a relative complex dielectric constant. The dielectric constant is a function of the permittivity and conductivity of the ground and of the frequency of the propagating signal.

In order to take the small scale roughness of the surface into account, an amplitude attenuation factor is used to modify the size of the specularly reflected component. This factor is a function of the rms roughness height, the wavelength, and the angle of incidence.

Usually only one specular ground reflection is calculated. However, there is a special option that can be used when computing ground reflections. This is the focusing ground option. This option will cause each plate to have a specular reflection associated with it.

2.1.1.2 Diffuse Ground Reflections.

Diffuse ground is modeled as a rough surface with a Gaussian height distribution and a Gaussian correlation coefficient. It is assumed that the rms height is much greater than the wavelength, that multiple scattering effects can be neglected, and that the radius of curvature everywhere on the scattering surface is much greater than the wavelength of the incident radiation.

The ground is divided into a grid of cells, and the diffuse reflection is calculated and summed for those cells which produce significant diffuse reflection. The significant cells are identified by using a channel spread function which gives the relative signal level as a function of the azimuth and elevation coordinate angles.

2.1.2 Building Reflections.

Each building surface is represented by a rectangular flat plate. The plate is characterized by its geometric location, including tilt from the vertical and height above grade, its dielectric constant, and its roughness. Complex buildings may be modeled by several rectangular flat plates with different characteristics as appropriate.

The scattering of the MLS signals from a building is calculated by applying Babinet's principle: scattering from a rectangular plate is equivalent to diffraction through a rectangular opening in an opaque screen.

2.1.2.1 Ray Paths.

Four ray paths may generate significant multipath from buildings. They are:

a. The path from the transmitter to the obstacle (building, aircraft) to the receiver, denoted by X-O-R.

b. The path from the transmitter to the ground, to the obstacle, to the receiver, denoted by X-G-O-R.

c. The path from the transmitter to the obstacle, to the ground, to the receiver, denoted by X-O-G-R.

d. The path from the transmitter to the ground, to the obstacle, to the ground, to the receiver, denoted by X-G-O-G-R.

The signal levels for paths b, c, and d are calculated using Babinet's principle (as is used for the X-O-R path) and the method of images. The changes in amplitude and phase of the signal when it bounces off the ground are determined by the ground roughness and by the dielectric constant of the ground.

The computation depends on the location of the specular point on the reflecting surface of the building. If the position of the specular point (X-O-R) does not lie within the region defined by the building rectangle, it is repositioned to the nearest edge.

2.1.2.2 Ground Correction.

The height of the ground between a transmitter and a building will, in general, be different from the height of the ground at the base of the obstacle. Since ground is included in computations for three of the above ray paths, the height of the ground is entered in the model input file as a ground correction height. Topographic data are used to determine this representative height of the ground between the transmitter and the reflecting building. If topographic data are not available, the ground height for a

reflecting obstacle may be chosen to be halfway between the height of the transmitter and the height of the obstacle. The selected height should be based on the transmitter which will be most affected by multipath from that obstacle.

2.1.3 Aircraft Reflections.

For calculating multipath reflections from aircraft, it is assumed that significant scattering comes only from the fuselage and from the vertical tail fin. Shielding by the wings is neglected. The fuselage and the tail fin are treated independently as cylinders and portions of cylinders, respectively.

2.1.3.1 Fuselage Model.

The fuselage of an aircraft is modeled as a horizontal, perfectly conducting, smooth cylinder. The cylinder extends from the nose of the aircraft to the leading edge of the tail fin. In order for scattering to occur, the transmitter and the receiver must be on the same side of the fuselage.

2.1.3.2 Tail Fin Model.

The tail fin is modeled as two sections of a vertical cylinder. The cylinder is smooth and perfectly conducting. The transmitter and the receiver must be on the same side of the tail fin for scattering to occur.

2.1.3.3 Cylindrical Scattering.

Scattering from a cylinder is calculated by solving the equivalent problem of diffraction by a rectangular aperture in an opaque plane (i.e. the same method used to calculate scattering from a building). The reflection coefficient is multiplied by a factor which accounts for the divergence of the rays due to the curved surface of the cylinder.

The computation depends on the location of the specular point on the cylinder. If the specular point does not lie on the cylinder, it is repositioned (within limits).

The geometry of the relative positions of the scattering aircraft, the ground, the transmitter, and the receiver may support bounce propagation paths. Multipath signals from the X-G-O-R, X-O-G-R, and X-G-O-G-R ray paths are calculated when this is the case, as is done in the calculation of building reflections.

2.1.3.4 Ground Correction.

As with the case of reflecting buildings, the height of the ground between a transmitter and a reflecting aircraft will in general be different from the height of the ground at the base of the

obstacle. Since ground is included in computations for three of the above ray paths, the height of the ground is entered in the model input file as a ground correction height. Topographic data are used to determine this representative height of the ground between the transmitter and the reflecting aircraft. If topographic data are not available, the ground height for a reflecting obstacle may be chosen to be halfway between the height of the transmitter and the height of the obstacle. The selected height should be based on the transmitter which will be most affected by multipath from that obstacle.

2.1.4 Shadowing.

Shadowing is the attenuation of the directly transmitted signal due to buildings and aircraft which obstruct or lie close to the line-of-sight between transmitter and receiver. Shadowing occurs when the geometric plane containing the obstacle is located between the transmitter and the receiver and the obstacle is in or near the transmitter-receiver line-of-sight so that a shadowing, and not a scattering, phenomenon is observed. Shadowing buildings might represent hangars or large trucks located at the side of the runway. Shadowing due to aircraft can occur in any of the following situations:

a. Blockage of transmitted signal by another landing aircraft on the same glidepath as the aircraft receiver.

b. Blockage of transmitted signal by an aircraft rolling out or possibly taking off over the azimuth site.

c. Blockage of transmitted signal by a taxiing aircraft passing through, or very near, the line-of-sight between the transmitter and aircraft receiver.

These cases are depicted in figure 3.

On many runways one end is higher than the other or the central part of the runway is higher than the ends. These differences in runway elevation may be sufficient to block the azimuth and DME/P signals when the aircraft is on final approach, at a low altitude, and close to threshold. This situation is called runway hump shadowing.

2.1.4.1 Shadowing by Buildings.

For the purpose of computing the shadowing effect, a building is modeled as a vertical flat plate perpendicular to the ground plane. No tilt is modeled. Babinet's principle is applied as before for building reflections. The attenuated signal is the sum of a combination of a direct wave and edge rays. The edge rays are assumed to have zero relative time delay. The specific combination

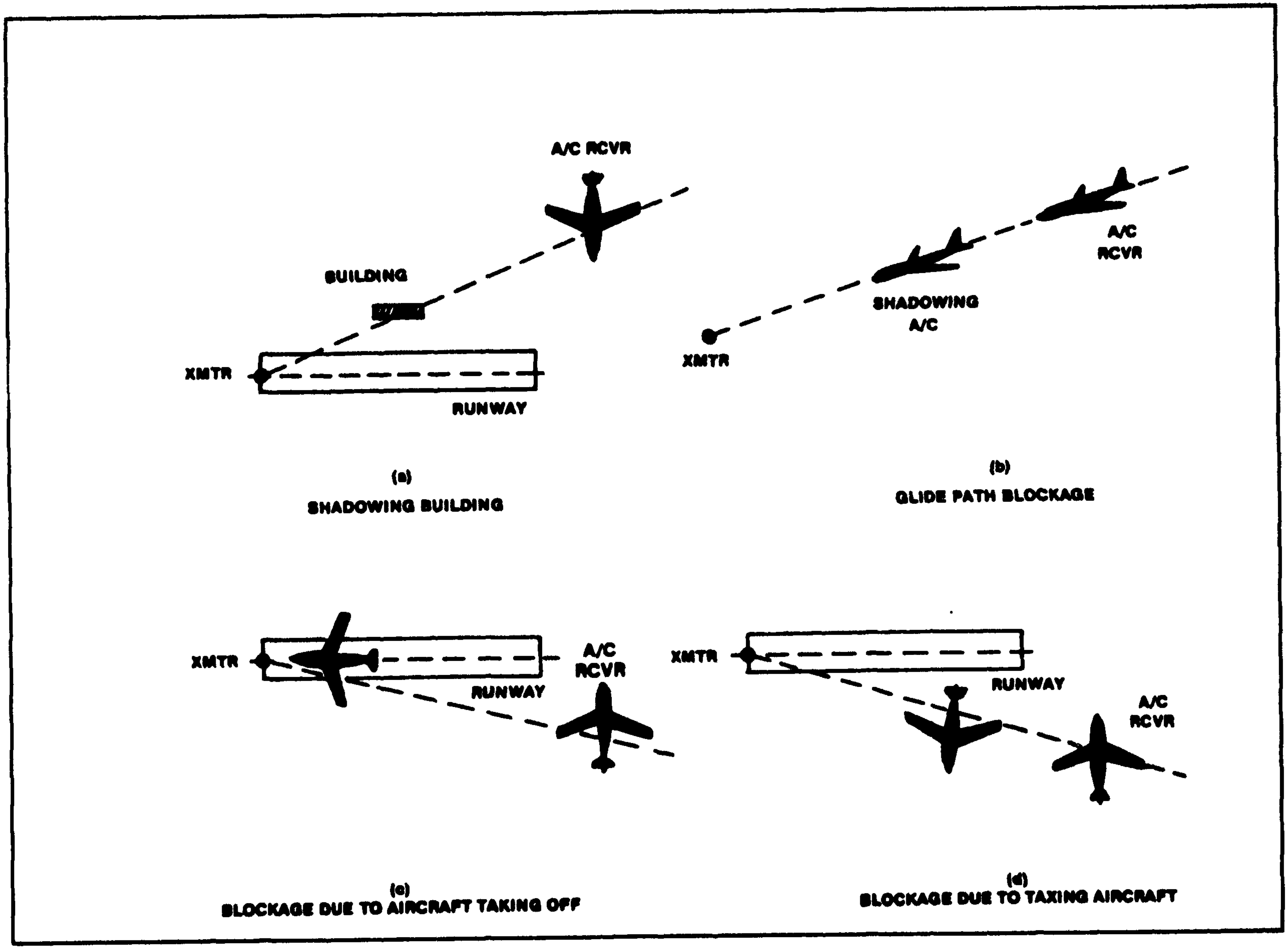

FIGURE 3. SHADOWING EFFECTS DUE TO BUILDINGS AND AIRCRAFT

of rays depends on where the line-of-sight path passes through the plane containing the rectangular obstacle.

Two propagation paths are modeled for each shadowing rectangle--an X-O-R and an X-G-O-R path. Experiments at Lincoln Laboratory concluded that the X-O-G-R and X-G-O-G-R paths generate insignificantly small signals for shadowing and can be neglected. The signal level is multiplied by the Fresnel reflection for the ground surface and by an attenuation factor for small scale roughness of the ground.

2.1.4.2 Shadowing by Aircraft.

Shadowing by an aircraft is calculated similarly to shadowing by a building. The silhouette of a shadowing aircraft is approximated by three rectangles. The orientation of the shadowing aircraft to the line-of-sight between the transmitter and receiver determines the viewing angle of the shadowing aircraft. Depending on the viewing angle, one of three silhouettes is chosen to represent the shadowing aircraft.

2.1.4.3 Shadowing by Runway Hump.

The attenuation of the directly transmitted signal due to a convex runway surface or runway hump is modeled by superimposing a cylindrical surface on the flat runway and then calculating the effect of the cylinder on the signal propagation using the Wait-Conda method. The axis of the cylinder is horizontal and perpendicular to the centerline of the runway.

The Wait-Conda method includes the specular ground reflection in its calculation of the shadowed direct wave. Therefore, when a runway hump shadows the direct signal and the Wait-Conda method is used, the computation of the specular ground reflection multipath component, discussed in section 2.1.1.1, is omitted. This may cause a discontinuity in the net computed multipath signal.

The runway hump shadowing calculation will not be performed if certain mathematical conditions, derived from the geometry, are not satisfied. Note that a runway hump will not shadow the elevation signal because the elevation transmitter is usually positioned close to the approach end of the runway.

2.2 PERTURBATION SMOOTHING.

The 0.2 foot wavelength of the MLS signal is very short. There is, therefore, the possibility that the signal levels may change significantly with small changes in the assumed aircraft locations. To see if this is the case, the propagation model has the option of calculating the multipath signals, not only at the nominal position of the aircraft, but at 12 nearby locations. A comparison then can

be made to see if there are large variations in signal levels with small changes in aircraft positions.

2.3 ANTENNAS.

The azimuth, elevation, and DME/P transmitters radiate their signal from their antennas which have three-dimensional radiation patterns. To simplify the model, each three-dimensional radiation pattern is represented as the product of two two-dimensional patterns. One dimension is the azimuth direction (horizontal), while the other is the elevation direction (vertical). It is assumed that the aircraft is always in the far field of the antenna. The receiving antennas on the aircraft are assumed to be omnidirectional.

The azimuth and elevation systems use scanning antennas; consequently, the antenna sidelobe amplitudes are functions of time. However, in the model it is assumed that the sidelobe amplitudes are constant.

The antenna gain factors are incorporated into the system model rather than the propagation model. All data from the propagation model are based on an omnidirectional radiation pattern.

The simulation program contains a library of antenna patterns for different MLS and DME/P equipment. The user can select the desired antenna patterns from this library.

2.4 SYSTEM MODEL.

2.4.1 Superposition.

The airborne equipment processes the envelope of the received signal which is the result of the superposition (addition) of the direct signal with all of the multipath signals, taking into account their relative magnitudes, phases, and time delays. The program BMLSR simulates this procedure.

2.4.2 Sampling Rates.

The specification of the aircraft velocity and the increment (sampling interval) by the user determines the sampling (data) rate. The propagation model is typically run so that it generates sampled data at a 5 hertz (Hz) rate. This sampling rate is required for the proper functioning of the PFE and the CMN filters in the system model. At every sampling point a new set of data values is produced, containing the amplitude, phase, time delay, direction of arrival of each significant multipath component, and the true values of the aircraft position.

The azimuth transmitter scans at a 13 Hz rate and the elevation transmitter scans at a 39 Hz rate. These rates are simulated in

the model by generating azimuth signals at a 15 Hz rate and elevation signals at a 40 Hz rate. The DME/P signals are modeled at a 40 Hz rate, which is typical of the Final Approach (FA) mode of the DME/P equipment.

2.4.2.1 Resampling the Multipath Signals.

Extrapolation is used to generate multipath signal samples at the 15, 40, and 40 Hz rates needed for the azimuth, elevation, and DME/P subsystems, respectively, from the 5 Hz rate provided by the propagation model. To simplify the computations, it is assumed that the following quantities do not change over the period of one 0.2 second sample interval:

a. The location of the specular points

b. The angles of arrival of the multipath components

c. The amplitudes of the multipath components

d. The aircraft velocity

The relative phase and time delay change as a function of aircraft position.

2.4.2.2 Doppler Velocity Correction.

The motion of the aircraft causes a Doppler shift in the frequency of the received signal. The change in the carrier frequency is insignificant and is ignored; however, the change in the phase of the received signal due to the Doppler shift is included in the model.

2.4.2.3 Resampling the True Azimuth and Elevation Angles.

The MLS errors are the differences between the angles calculated by the receivers and the true angular positions of the aircraft. The angular positions of the aircraft are sampled at a 5 Hz rate, the same rate as the multipath signals. A comparison of the calculated angles with the true angles requires that the true angles be resampled at the 15 Hz and 40 Hz rates also, using the velocity and acceleration correction option.

The user has this option of selecting or of not selecting the velocity and acceleration correction feature. Selecting this option causes the simulation, when calculating the true position of the aircraft, to use a polynomial fitting method to resample the data instead of assuming that the data values remain unchanged between the calculated samples. The resampling is done by fitting a second order polynomial to the current sample and the two previous samples. In addition, selecting this option causes the

simulation to apply the Doppler correction to the phases of the received signals.

2.5 PROCESSING OF THE AZIMUTH AND ELEVATION SIGNALS.

The TRSB radio navigation aid works in the following way. A fan shaped "radar" beam scans back and forth over the volume of airspace containing the aircraft. The aircraft receives a signal pulse each time the beam sweeps by and measures the times of arrival of the TO and FRO pulses. The time delay between the two arrivals is proportional to the direction of the aircraft from the transmitter. The azimuth transmitter scans back (TO) and forth (FRO) horizontally; the separate elevation transmitter scans up and down vertically.

The critical measurement in the receiver is the time of arrival of the received pulse. The receiver processing algorithms locate the pulse and measure either the positions of the leading and trailing edges (dwell gate processing) or the position of the pulse peak (split gate processing). Multipath signals superimposed on the direct signal distort the shape of the pulse causing errors in these measurements.

2.5.1 Acquisition Mode.

Acquisition is the establishment of a track. It has two steps: (1) determination of a likely candidate to be tracked, and (2) accumulation of enough data to give reasonable assurance that the candidate to be tracked is a valid signal and is, on the average, the largest component and therefore, the direct component. Should invalid data be received during track mode, a coast mode is provided to maintain track for 1 second. If the receiver drops out of track at some point, reacquisition is initiated. Reacquisition is identical to the initial acquisition process.

2.5.1.1 Candidate Selection.

During the first received signal frame, the receiver searches for the largest signal in the TO part of the scan and the largest signal in the FRO part of the scan. The peaks or maximum signal values are considered to be the arrival times of the pulses. If the two peaks are within 50 microseconds (pulse symmetry), it is assumed that they correspond to the same signal, and tracking gates are set up centered on the peaks. A tracking gate is a time interval in which the next received pulse is expected. At this point in the acquisition, a candidate or tentative track has been established. The second phase of the acquisition, track confirmation, is now entered.

2.5.1.2 Track Confirmation.

The candidate signal is tracked until confidence is established that it is the true track. For this purpose, the receiver contains two counters: a confidence counter and a frame counter. Each counter can be incremented, decremented, or cleared (reset to zero). The confidence counter is incremented when the received signal peaks fall within the tracking gates and decremented otherwise. This means that for the confidence counter to be incremented, the tracked component must exceed any out-of-beam signals at least 50 percent of the time. The frame counter is incremented when the received signal peaks pass three validation checks; otherwise it is decremented.

2.5.1.2.1 Validation Tests.

The validation checks are pulse width, pulse number, and pulse symmetry. Each is discussed below.

2.5.1.2.1.1 Pulse Width Test.

The dwell gate is the time interval when the signal is illuminating the aircraft. There is a dwell gate for the TO signal and for the FRO signal. It is defined to be the time interval between the start of the pulse and the end of the pulse. The start or leading edge of the pulse is the point on the pulse which is 3 decibels (dB) lower than the peak and precedes the peak. The end or trailing edge of the pulse is the point on the pulse which is 3 dB lower than the peak and follows the peak.

The pulse width is the time difference between the leading and trailing edges of the pulse. The width must satisfy maximum value and minimum value checks to pass the pulse width test.

2.5.1.2.1.2 Pulse Number Test.

Only one pulse is allowed within the dwell gate time interval. Otherwise this test is failed.

2.5.1.2.1.3 Pulse Symmetry.

The time difference between the TO and FRO arrival times must be less than a specified maximum value (50 microseconds). This is the same test used in selecting a candidate track.

2.5.1.2.2 Confirmation.

Any time either the frame counter or the confidence counter is decremented to zero, the candidate track is dropped and reacquisition begins.

If the frame counter reaches saturation, 20 counts for elevation and 8 counts for azimuth, the candidate track is accepted as valid, and the receiver enters tracking mode.

2.5.2 Tracking Mode.

In tracking mode, validation tests are performed. When the scan is validated, the raw angle error is computed by numerical simulation.

2.5.2.1 Validation Tests.

During tracking, the validation tests used during the acquisition phase are continued. Their outputs are processed in exactly the same way relative to the counters. The track is lost whenever either the frame counter or the confidence counter is reset to zero.

2.5.2.2 Filtering.

The raw pulse arrival times are alpha-beta filtered (and then slew limited) to produce smoothed arrival times.

2.5.2.2.1 Arrival Times.

The model has two methods of determining the time of arrival of the signal envelope or pulse: dwell gate processing and split gate processing. The former method finds the leading and trailing edges of the received pulse as described previously in section 2.5.1.2.1.1. The arrival time of the pulse is then the average of the times for the leading and trailing edges. The latter method determines the arrival time based on the location of the peak of a pulse.

2.5.2.2.2 Alpha-Beta Tracker.

The raw arrival times are fed into an alpha-beta (second order) tracking filter which produces smoothed estimates of the arrival times.

2.5.2.3 Slew Limiting.

The true azimuth and elevation angles of the aircraft cannot change faster than the aircraft can move. A sudden jump in an arrival time of the direct signal is physically impossible and, therefore, indicates that the measurement is in error. The smoothed arrival times output by the filter are checked for too rapid a change in value, i.e., a too-high slew rate. The maximum allowed slew rate is 1° per second. If the slew rate is higher than this value, a slew rate violation has occurred. When a violation occurs, the new smoothed value is set at the limit and the frame counter is decremented (depending on the polarity of the slew violation).

2.5.2.4 Angle Calculation.

Following passage of all the validation tests on a given scan pair, there remains an arrival time for the TO pulse and an arrival time for the FRO pulse. The angle (either azimuth or elevation) is calculated by multiplying the average of the arrival times by the scan rate of the appropriate transmitter.

2.5.3 Coast Mode.

When a valid angle measurement for a given scan is not found, the tracking mode switches into coast mode for that scan. The coast consists of extrapolating the angular coordinates linearly at the most recent velocity estimates.

2.6 PFE AND CMN REQUIREMENTS.

The system model reports the position errors of the aircraft in terms of the aircraft's azimuth, elevation, and range. The error is the difference, for each function, between the simulated output value of the receiver/transponder and the true value. To evaluate the performance of the MLS and DME/P against specified error tolerances, the raw error values are further filtered by two filters.

One filter is the PFE filter. It is a low pass filter and passes those frequency components of the error that might cause the aircraft, while under autopilot control, to deviate from its flightpath. The cutoff frequencies are normally 0.5 radians per second for azimuth and 1.5 radians per second for elevation and DME/P.

The other filter is the CMN filter which is a high pass filter. It passes those frequencies that cause the aircraft controls to move or vibrate (when the MLS and DME/P drives the autopilot) without causing aircraft displacement from the flightpath.

Unnecessary deviations from the flightpath can cause wasted motion, passenger discomfort, and possible difficulty in reattaining the flightpath. Unnecessary control surface movement or vibration shortens the life of the control system and may cause a lack of pilot confidence in the guidance of the MLS system. If either of these error measures exceed their respective limits, the guidance is unacceptable and corrective action is necessary.

For these reasons, the performance accuracy of the MLS and DME/P is specified by limits on the PFE and CMN. The computer model of MLS also calculates the PFE and CMN errors for the scenarios and flightpaths simulated.

2.7 PROCESSING OF THE DME/P SIGNALS.

The DME/P model simulates the range errors caused by multipath effects on the DME/P part of the MLS system. The propagation model generates the multipath amplitudes, phases, time delays, and angles in a manner similar to that used for the MLS system. The major difference is that the DME/P system consists of a transponder on the ground and an interrogator in the aircraft. Therefore, signals are transmitted in both directions with different multipath characteristics. To accommodate this difference, the propagation model simulates these transmittals as an uplink and a downlink multipath signal for each obstacle.

The DME/P system model includes additional error sources such as thermal noise and reply efficiency. The model permits the selection of different pulse shapes, intermediate frequency (IF) filters, and trigger circuits. The raw range error, which is output from the DME/P model, can be further processed through PFE and CMN filters and plotted with the appropriate tolerance values to assess the system's performance acceptability.

As with the MLS, the propagation model for DME/P computes multipath pulse amplitudes, phases, time delays, and angles of transmittal and reception. Amplitudes, phases, and time delays are computed relative to the direct signal which has unit amplitude with zero phase and time delay. The total phase shift of the multipath signal is the sum of the phase shift due to the reflecting obstacle and the phase shift caused by the longer travel time of the multipath signal.

The system model combines the multipath signals from all obstacles at a given sampling point along the flightpath into a composite pulse shape. A noise value is also applied to this computed pulse shape. The distorted pulse is compared with an undistorted reference pulse in the trigger circuits to compute the raw error for that sampling point. This procedure is repeated for each flightpath point.

2.7.1 Calculation of Thermal Noise.

Beginning with the specified signal-to-noise ratio in dB, a noise value relative to the IF filter input is computed after a distance correction. This noise value represents the relative noise level at the start of the simulation. Since the signal amplitude increases during an approach, the signal-to-noise ratio will also increase. In the model, the value of the direct signal is always one. Therefore, the increase in signal-to-noise ratio is simulated by decreasing the effective noise level as a function of the slant range between the airborne and ground antennas.

The thermal noise and reply efficiency are simulated by using a standard pseudo random number generator with a period of 2^{29} calls. This generator provides uniformly distributed random numbers between 0 and 1. A special algorithm converts the uniform distribution into a Gaussian distribution for the thermal noise simulation.

2.7.2 Calculation of Reply Efficiency.

Reply efficiency is simulated by using the uniformly distributed random numbers as obtained from the random number generator. If a particular value is greater than the desired reply efficiency, an unrealistic range value will be generated which will be eliminated by falling outside the tracking gate.

2.7.3 Tracking Filter.

The measured distance values are passed through a simulated alpha-beta filter. This filter smoothes the raw range errors, thus reducing the overall error noise. In addition, this filter also replaces missing data (i.e., data outside the tracking gate) with weighted estimates.

Tracking begins when the third validated range value is computed. A variable width tracking gate (dependent upon the expected measurement noise) is applied to all subsequent data. A confidence counter is simulated which provides an out-of-track flag if no signal is within the tracking gate for more than 1 second.

2.7.4 Accuracy Assessment.

The simulated output range is compared to the reference flightpath data, and the deviation is computed by taking the difference: measured distance minus reference distance. This difference is called the raw error. The raw error is further processed by two error filters, the PFE filter and the CMN filter. The low frequency components of the error signal cause an aircraft to deviate from the desired flightpath. The PFE filter filters these frequency components out of the error spectrum. The higher frequency components of the error signal cause undesired motion of the aircraft control devices, hence unallowable mechanical stress. The CMN filter identifies these frequency components.

The output of the PFE and CMN filters is subjected to a sliding time window of 10 seconds (i.e., about 400 points) which is moved along the error plot from start to end of the flightpath. This window is advanced one point at a time. The error tolerance limits must not be violated in more than 5 percent of the window. In order to take care of an assumed equipment error of 10 meters, the error limits are shifted by that amount in the positive and negative direction when checking the PFE. The equipment error has

no effect on the CMN because the CMN filter is a bandpass. For each window position, the number of violations is counted separately for the two shift directions. The maximum number occurring in each window position is stored and displayed on the plots (100 percent = 10 seconds or 400 points outside limits).

3. OPERATION OF THE MATHEMATICAL MODEL.

3.1 SIMULATION OPTIONS.

The mathematical model has a number of processing options selectable by the user. The options are determined by the contents of the input data file and by interactive user input during run time. The main options available to the user are the selection of the types of scattering and shadowing obstacles to be considered in the airport environment that is being simulated.

3.1.1 Shadowing Options.

There are two types of shadowing options: (1) shadowing produced by buildings or by aircraft and (2) shadowing produced by a runway hump. Only one shadowing option can be simulated in a single run. If shadowing by buildings and/or aircraft is selected, the program will not perform runway hump shadowing, even if it is requested and the proper parameters are entered, nor will it simulate specular ground reflections from surface elements (rectangles and/or triangles) and the default ground. The reason is that additional ground reflection components (based on field test results) are computed in the shadowing subroutine, and these ground reflection computations are not the same as those used in the specular ground reflection subroutine and may tend to give different results. The two ground computations are made mutually exclusive to avoid this conflict.

Runway hump shadowing will be performed only if shadowing by buildings and/or aircraft has not been requested. The specular ground reflection calculations are also disabled for those portions of the receiver flightpath for which the runway hump is in line-of-sight between the azimuth or DME/P transmitter and the receiver. The runway hump calculations, like those for shadowing buildings and aircraft, calculate ground reflections independently from the specular ground reflection subroutines. The latter are disabled to avoid conflicting results. Runway hump shadowing is not performed for the elevation antenna.

3.1.2 Scattering Options.

The types of scattering obstacles that can be defined through the input file are buildings and aircraft. Buildings are represented by rectangles. The location, size, and surface characteristics are defined by the user. These rectangles can be used to simulate any type of rectangular object such as buildings, portions of

buildings, antenna structures, lights, etc. The characteristics of each aircraft type are supplied to the programs by a built-in data base. The available aircraft types are discussed in section 3.2.3.4.

Several options are also available for determining the scattering effects of the ground. These are discussed in the following sections.

3.1.3 Ground Reflection Options.

There are several specular and focusing ground reflection options which are determined by the data in the input file. The default option is to process specular reflections with the ground as an infinite flat plane (at Z=0) with perfect conductivity (dielectric constant and roughness factor both set to zero). To change this default, the user must include section 2 in the input file (see section 3.2.3.3). In this section, the first question is a switch that can disable all specular ground reflections. If this section is present and specular ground reflections are enabled, the user may specify alternative values for the default dielectric constant and roughness for ground. The second question is a switch to determine the algorithm used in ground reflection calculations. The default is full Fresnel-Kirchoff integration for ground reflection processing. The alternative option is to calculate ground reflections using an approximate Fresnel coefficient.

Another ground reflection option permits the definition of a number of tilted surface elements. These elements may be rectangular or triangular in shape. Each element may have its own complex dielectric constant and roughness factor. Tilted surface elements are calculated using full Fresnel-Kirchoff numerical integration, which is the default option. If the approximate Fresnel coefficient is chosen in section 2, the tilted surface elements will not be processed even if they are requested and the proper parameters are entered. There is the option to determine the focusing effect of these surfaces at the receiver by computing the specular reflection from each surface by setting the surface flag (SF) to 1.

The ground may also be considered a diffuse scatterer. In this case, the surface that reflects signals is defined by a ground roughness height and correlation distance for each transmitter. The cumulative multipath amplitude is calculated, using random phase shifts, to determine the effect of this scattering on the guidance accuracy.

3.1.4 Perturbation Smoothing Option.

The perturbation smoothing option creates 12 additional flightpath points (3 above, 3 below, 3 to the right, and 3 to the left) for each of the basic flightpath points. Computations for multipath

and shadowing are done at all 13 points to avoid the possibility that the single point will not be representative of a problem area due to the short wavelength of the MLS (0.2 feet) compared to the distance between flightpath points (40 feet).

3.1.5 Other Options.

Other options (see "Execution Guides", section 3.3) include the ability to select specific transmitters to be used during the simulation. This option can save run time when specific transmitters are of interest or the parameters of only one transmitter have been changed since a previous run. This selection can be made during the run time of each of the four programs of the model.

There is a choice of azimuth, elevation, and DME/P antenna types which can be simulated based on the selection entered in the input file. These choices are listed in table 1.

The user can also select the type of receiver algorithm to be used. The angle receiver can operate as either a dwell gate processor or a split gate processor. This selection is made during run time of the system model program BMLSR.

Error computations can also include velocity and acceleration corrections during the receiver processing, if desired. The velocity and acceleration correction factor modifies the estimated and direct signal angles to compensate for the multiple scans during one frame of model data. The model error data are generated as three azimuth or eight elevation scans for each model frame (at the 5 Hz rate). Since the frame has one set of X, Y, Z coordinates, the correction factor is used to anticipate changes in position for each scan within the model frame. This correction avoids step-wise error data as input to the receiver alpha-beta filter. Step-wise errors will only be noticeable when the receiver is moving orthogonally to the transmitter, as with an orbit flightpath. The selection of velocity and acceleration corrections is made during run time of the system model program BMLSR.

3.2 MATHEMATICAL MODEL INPUT.

The input data for the model programs are entered using a formatted (ASCII) input file. The file is divided into 16 sections. Each section contains data for a specific aspect of the model. The data categories for each section are listed in table 2. The formatted input file created by the user is read directly by the program BMLST. Copies of the input file are written by each program to all output files to pass required data to the next program in the simulation.

A formatted input file is created from the input file template distributed with the model source code (called INPUT.FIF). The

TABLE 2. CATEGORIES OF INPUT DATA (INPUT FILE SECTIONS)

Section	Description
(0)	Scenario description
(1)	Transmitters
(2)	Ground characteristics
(3)	Aircraft (scatterers)
(4)	Building (scatterers)
(5)	Rectangular ground plates
(6)	Triangular ground plates
(7)	Diffuse scattering from ground
(8)	Shadowing by aircraft
(9)	Shadowing by buildings
(10)	Shadowing by runway hump
(11)	Runway profile
(12)	Flightpath of simulated aircraft
(13)	Plot scale limits for flightpath and airport layout plots
(14)	Plot scale limits for multipath diagnostic and error plots for azimuth and elevation subsystems
(15)	Plot scale limits for multipath diagnostic and error plots for DME/P subsystem

template contains headings indicating the expected data for each section and template strings indicating the position and field size of the data. In some cases, the template strings are replaced by data. In others, the data are entered underneath the template string. Section 3.2.1 illustrates the input file template while section 3.2.2 provides additional details for the creation of an input file for a specific simulation. The input file can be created from the input file template using any editor that will produce pure ASCII output (no editing, formatting, or other special characters). The format of the input file must be strictly maintained since this is the format that the programs expect to read. An example of an input file created from the input file template for a specific scenario is provided in the appendix, table A-1.

3.2.1 Formatted Input File Template.

This section contains the formatted input file template. Descriptions of the parameters used for each input file section are given in section 3.2.3.

```
********************MLS MATHEMATICAL MODEL INPUT DATA FILE***********************
SECTION  0
          = SCENARIO DATA
          RUN ID# :####
          TITLE   :tttttttttttttttttttttttttttttttttttttttttttttttttttttttttt
          AIRPORT :aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
          RUNWAY  :rrrrr
          LENGTH  :lllll
          WIDTH   :wwwww
          ARDH    :ttttt
          MGPA    :mmmmm
          UNITS   :FEET   (feet, meter) FOR ENTRIES IN FILE
SECTION 1A
          = ANGLE TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z     FREQ(mhz)  LSL   USL    TYPE
                      -------- -------- -------- --------- ----- ----- --------
          AZIMUTH   : xxxxxxxx yyyyyyyy zzzzzzzz fafafafaf lllll uuuuu tttttttt
          ELEVATION: xxxxxxxx yyyyyyyy zzzzzzzz fafafafaf lllll uuuuu tttttttt
SECTION 1D
          = DME/P TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z      TYPE
                      -------- -------- -------- --------
          DME/P     : xxxxxxxx yyyyyyyy zzzzzzzz tttttttt

          = OTHER DME DATA
                    FREQ(mhz)  SHAPE    TRG  F   SW    AS    TRS  SIGN   RMI
                    --------- --------- --- --- ----- ----- ----- ----- -----
          UPLINK    : fafafafaf sssssssss ttt fff swsws aaaaa trtrt sisis rrrrr
          DOWNLINK : fafafafaf sssssssss ttt fff swsws aaaaa trtrt sisis rrrrr
SECTION  2
          rrr - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
          rrr - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
          = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
          DIELECTRIC CONSTANT : rrrrrrrrrr iiiiiiiii
          ROUGHNESS HEIGHT    : rrrrrrrrrr
         * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
          DIELECTRIC CONSTANT : rrrrrrrrrr iiiiiiiii
          ROUGHNESS HEIGHT    : rrrrrrrrrr
SECTION  3
          = SCATTERING FROM AIRCRAFT (MAXIMUM OF 10)
          rrr - RUN AIRCRAFT SCATTERING (yes,no)
       ## X-TAIL   Y-TAIL   X-CKPT   Y-CKPT    ALT    AT  GRCORR
       -- -------- -------- -------- -------- -------- -- --------
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy aaaaaaaa tt cccccccc
SECTION  4
          = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
          rrr - RUN SCATTERING BUILDINGS (yes,no)
       ## X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT   GRCORR   CMP
       -- -------- -------- -------- -------- ----- ----- ----- -------- -----
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
SECTION  5
          = SPECULAR SCATTERING FROM RECTANGULAR GROUND SURFACES (MAX OF 10)
          rrr - RUN RECTANGULAR GROUND (yes,no)
          THIS SECTION MAY BE SKIPPED DEPENDING ON ANSWERS IN SECTION 2
       ## X-VALU   Y-VALU   Z-VALU   DCREAL   DCIMAG   ROUGHN   SF
       -- -------- -------- -------- -------- -------- -------- --
       nn x1x1x1x1 y1y1y1y1 z1z1z1z1 rrrrrrrr iiiiiiii rrrrrrrr is
          x2x2x2x2 y2y2y2y2 z2z2z2z2
          x3x3x3x3 y3y3y3y3 z3z3z3z3
SECTION  6
          = SPECULAR SCATTERING FROM TRIANGULAR GROUND SURFACES (MAXIMUM OF 10)
          rrr - RUN TRIANGULAR GROUND (yes,no)
          THIS SECTION MAY BE SKIPPED DEPENDING ON ANSWERS IN SECTION 2
       ## X-VALU   Y-VALU   Z-VALU   DCREAL   DCIMAG   ROUGHN   SF
       -- -------- -------- -------- -------- -------- -------- --
       nn x1x1x1x1 y1y1y1y1 z1z1z1z1 rrrrrrrr iiiiiiii rrrrrrrr is
          x2x2x2x2 y2y2y2y2 z2z2z2z2
          x3x3x3x3 y3y3y3y3 z3z3z3z3
```

```
SECTION  7
          = DIFFUSE SCATTERING FROM GROUND
          rrr - RUN DIFFUSE SCATTERING (yes,no)
                     SIGH     SIGL
                   -------- --------
          AZIMUTH  : hhhhhhhh llllllll
          ELEVATION: hhhhhhhh llllllll
          DME/P    : hhhhhhhh llllllll
SECTION  8
          = SHADOWING BY AIRCRAFT (MAXIMUM OF 10)

          rrr - RUN SHADOWING AIRCRAFT (yes,no)
       ##  X-VALU   Y-VALU   Z-VALU   VEL   ANG  AT
       -- -------- -------- -------- ----- ----- --
       nn sax1sax1 say1say1 saz1saz1 vvvvv aaaaa tt
          sax2sax2 say2say2 saz2saz2
SECTION  9
          = SHADOWING BY BUILDINGS (MAXIMUM OF 10)
          rrr - RUN SHADOWING BUILDINGS (yes,no)
       ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT
       -- -------- -------- -------- -------- ----- -----
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh
SECTION 10
          = SHADOWING BY RUNWAY HUMP
          rrr - RUN SHADOWING HUMP (yes,no)
           X-FRONT  Z-FRONT  X-HUMP   Z-HUMP   X-BACK   Z-BACK
          -------- -------- -------- -------- -------- --------
          xfxfxfxf zfzfzfzf xhxhxhxh zhzhzhzh xbxbxbxb zbzbzbzb
SECTION 11
          = RUNWAY PROFILE (MAXIMUM OF 20 POINTS)
       ##    XP       YP       ZP
       -- -------- -------- --------
       rp xxxxxxxx yyyyyyyy zzzzzzzz
SECTION 12
          = FLIGHTPATH
          FAF      : fffff  NAUTICAL MILES
          DATUM    : xxxxxxxx yyyyyyyy zzzzzzzz
          TYPE     : fpfpfpfpf   (measured,distance,orbit,radial,
       *                           segmented,straight)
          VELOCITY : vvvvvvvv
          INCREMENT: iiiiiiii
          DATA RATE: dddddddd
       *  IF "straight" SUFFICIENT DATA ARE AVAILABLE TO COMPUTE FLIGHTPATH
       *  IF "radial" ENTER ANGLE,ELEVATION & STARTING AND ENDING DISTANCES
       *              (nm from dme/p)
          ANGLE: aaaaaaaa
          SDIST: dddddddd
          EDIST: dddddddd
          ELEV : eeeeeeee
       *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
          RADIUS: rrrrrrrr
          ELEV  : eeeeeeee
       *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
       *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
       *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
       *      INCREMENT
       ##    XS       YS       ZS       VEL      INC
       -- -------- -------- -------- -------- --------
       nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
```

```
SECTION 13
        = FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS
      * FLIGHTPATH PLOTS:
                              X/Y PLOT      X/Z PLOT      D/Z PLOT
                             ----------    ----------    ----------
        MINIMUM X VALUE :    xyxyxyxyxy    xzxzxzxzxz    dzdzdzdzdz
        UNITS PER INCH  :    xyxyxyxyxy    xzxzxzxzxz    dzdzdzdzdz
        MINIMUM Y VALUE :    xyxyxyxyxy    xzxzxzxzxz    dzdzdzdzdz
        UNITS PER INCH  :    xyxyxyxyxy    xzxzxzxzxz    dzdzdzdzdz
      * AIRPORT LAYOUT PLOT:
                              X/Y PLOT
                             ----------
        MINIMUM X VALUE :    xyxyxyxyxy
        UNITS PER INCH  :    xyxyxyxyxy
        MINIMUM Y VALUE :    xyxyxyxyxy
        UNITS PER INCH  :    xyxyxyxyxy
SECTION 14
        = ANGLE EQUIPMENT AXIS LIMITS
      * MULTIPATH DIAGNOSTIC PLOTS:
                                M/D        SEP ANG      SHADOWING
                             ---------    ---------    ---------
        MINIMUM X VALUE :    mdmdmdmdm    sasasasas    shshshshs
        UNITS PER INCH  :    mdmdmdmdm    sasasasas    shshshshs
        MINIMUM Y VALUE :    mdmdmdmdm    sasasasas    shshshshs
        UNITS PER INCH  :    mdmdmdmdm    sasasasas    shshshshs
      * RECEIVER ERROR & FILTERED ERROR PLOTS:
                                RAW          PFE          CMN
                             ---------    ---------    ---------
        MINIMUM X VALUE :    rrrrrrrrr    ppppppppp    ccccccccc
        UNITS PER INCH  :    rrrrrrrrr    ppppppppp    ccccccccc
        MINIMUM Y VALUE :    rrrrrrrrr    ppppppppp    ccccccccc
        UNITS PER INCH  :    rrrrrrrrr    ppppppppp    ccccccccc
SECTION 15
        = DISTANCE MEASURING EQUIPMENT AXIS LIMITS
      * MULTIPATH DIAGNOSTIC PLOTS:
                                M/D        TIM DELAY    SHADOWING
                             ---------    ---------    ---------
        MINIMUM X VALUE :    mdmdmdmdm    tdtdtdtdt    shshshshs
        UNITS PER INCH  :    mdmdmdmdm    tdtdtdtdt    shshshshs
        MINIMUM Y VALUE :    mdmdmdmdm    tdtdtdtdt    shshshshs
        UNITS PER INCH  :    mdmdmdmdm    tdtdtdtdt    shshshshs
      * INTERROGATOR ERROR & FILTERED ERROR PLOTS:
                                RAW          PFE          CMN
                             ---------    ---------    ---------
        MINIMUM X VALUE :    rrrrrrrrr    ppppppppp    ccccccccc
        UNITS PER INCH  :    rrrrrrrrr    ppppppppp    ccccccccc
        MINIMUM Y VALUE :    rrrrrrrrr    ppppppppp    ccccccccc
        UNITS PER INCH  :    rrrrrrrrr    ppppppppp    ccccccccc
END DATA
```

3.2.2 Notes on the Input File Format.

a. Not all sections must exist, however sections 0 and 1 should always exist.

b. The sections are not required to be in any particular order in the file with the exception of sections 5 and 6. If 5 and 6 both exist, section 5 must appear in the file before section 6.

c. The last record in the file must be END DATA.

d. If a section does exist, so must the header information and labels for that section.

e. Sections 3-6, 8-11, and the segmented flightpath portion of section 12 must include a copy of the template strings after the header information.

f. Data must follow the template strings in sections 3-6, 8-11, and the segmented flightpath portion of section 12, if that section is used. Data are ignored if the section flag is set to NO.

g. In sections 0-2, 7, 12, 13, and 14 data are expected in place of the template strings.

h. In sections 1A and 1D, antenna types must be entered in uppercase and left justified in the data field. The filter type for DME/P must also be specified, in section 1D, in upper case.

i. In sections 3-10, questions requiring a response may have upper or lowercase YES, NO, Y or N for a valid response.

1. If the response is not YES or NO, a warning message is printed, and the response is assumed to be NO.

2. If the response is NO or assumed NO, data (if any) following the template string are skipped.

3. If the response is YES and data follows the template string, they are read up to the maximum allowable elements (usually 10). If data exist beyond the maximum, a warning message is printed notifying the user that extra data existed but were not accepted.

4. If the response is YES but no data follow the template string, a warning message is printed, and the response is assumed to be NO.

j. The flightpath type entered in section 12 must be left justified in the data field but may be upper or lower case.

k. For any sections that do not exist among sections 3-10, default values will be used. However, if in section 2, ground reflection processing and/or full integration are answered NO, sections 5 and 6 will be skipped.

3.2.3 Detailed Description of the Input Parameters.

This section discusses the formatted input file in detail, section by section. The model coordinate system is a right-handed coordinate system with its origin on the centerline at the stop end of the runway. The positive X axis points along runway centerline in the direction of the threshold and the positive Z axis points up.

3.2.3.1 Section 0 (Airport) Description.

Section 0 contains information helpful to the user in later evaluation of the simulation results. The first four items uniquely identify the simulation. These data are written to all output files and are displayed on all plots. The runway length (LENGTH), approach reference datum height (ARDH), and minimum glide path angle (MGPA) are used in calculations for the error tolerance lines. The runway width (WIDTH) is used in the Wait-Conda method of calculating runway hump shadowing.

RUN ID - The user identification number for this run

TITLE - An explanatory title for the run

AIRPORT - Airport identification (for example: ACY, LAX, DCA)

RUNWAY - The runway number

LENGTH - The usable runway (listed) length

WIDTH - The usable runway (listed) width

ARDH - Approach reference datum height

MGPA - Minimum glidepath angle

UNITS - The units of linear measure used in data entry (currently feet only - will be expanded to include meters).

3.2.3.2 Section 1 (Transmitter) Description.

Section 1 contains information on the MLS transmitters. There are four transmitters modeled:

a. Azimuth
b. Elevation
c. DME/P uplink
d. DME/P downlink

The data for the azimuth and elevation transmitters are specified in subsection 1A. The data for the DME/P transmitters are specified in subsection 1D. (The "A" in 1A indicates "angle" equipment; the "D" in 1D indicates "precision distance measuring equipment.")

LOCATION (X Y Z) - The location of the transmitter phase center, specified in the model coordinate system.

FREQUENCY - The frequency (FREQ) of the transmitter in megahertz (MHz). The azimuth and elevation transmitters should be of the same frequency in the band 5030-5090 MHz. The DME/P operates in the frequency band 960-1215 MHz.

SCAN LIMITS - The lower (LSL) and upper (USL) scan limits in degrees specified for each scanning beam antenna.

TYPE - The antenna type which determines the antenna pattern and beam-width. It can be found by referring to the list of antenna types available in table 1. The first letter of the antenna type must be in the first column (i.e., must replace the first character of the template string). The antenna type must be specified in uppercase.

The parameters specific to DME/P are as follows:

SHAPE - The shape of the envelope of the DME/P pulse (available choices listed in table 3).

TRG - The method used to threshold the received pulse (choice is either DAC for Delay-Attenuate-Compare or PAF for Peak-Amplitude-Find).

F - The type of filter (available choices listed in table 4).

SW - The relative threshold used with PAF for determining the time of arrival of the pulse.

AS - The attenuation value used for DAC thresholding.

TRS - The trigger point on the rising edge of DAC.

SIGM - Additive noise variance at the beginning of the flightpath (at maximum distance)

RMI - The mean value of noise.

<u>3.2.3.3 Section 2 (Specular Ground) Description</u>.

Section 2 contains the information necessary to compute reflections from the ground in the airport environment.

GROUND REFLECTION FLAG - The answer to the first question sets a flag to determine if ground reflection computations are to be done. If YES, ground reflections

TABLE 3. AVAILABLE PULSE SHAPES FOR DME/P MODEL

Shape Code	Rise Time	Leading Edge	Trailing Edge
PCOC20800	0800 ns	Cosine	Cosine-squared
PCOC21000	1000 ns	Cosine	Cosine-squared
PCOC21200	1200 ns	Cosine	Cosine-squared
ICOC22200	2200 ns	Cosine	Cosine-squared
NC2C21600	1600 ns	Cosine-squared	Cosine-squared
GC2C22000	2000 ns	Cosine-squared	Cosine-squared

TABLE 4. DME/P FILTER TYPES

Filter Type	Filter Code
None	NOF
Lowpass	LOW
Butterworth, 8 pole	B8P
Butterworth, 4 pole	B4P
Notch	NOT

are computed. This is the default, even if section 2 is not present in the input file.

INTEGRATION FLAG - The answer to the second question sets a flag to determine if full Fresnel-Kirchoff integration will be calculated for ground reflections from tilted surface elements and from the default ground. The default is YES, perform full Fresnel-Kirchoff integration. If the flag is answered NO, an approximate Fresnel coefficient is used for default ground reflection, and tilted ground elements are not processed, even if they are present in the input file.

DEFAULT CONSTANTS - The default dielectric constant (real and imaginary) and the rms roughness height for the ground, specified for use for the default ground in the building, aircraft, and ground reflection routines.

3.2.3.4 Section 3 (Scattering Aircraft) Description.

Section 3 contains information on scattering aircraft. The answer to the first question sets a flag to determine if aircraft reflections are to be simulated.

ID NO. (##) - Two-character identification for each scattering aircraft.

ENDPOINTS - The X and Y coordinates (tail, cockpit) of the aircraft endpoints, tail end specified first.

ALTITUDE (ALT) - The altitude of the fuselage centerline above the zero Z reference. If this value is zero, a default altitude value for the specified aircraft type will be used based on the assumption that the ground under the aircraft is at the zero Z reference.

AIRCRAFT (AT) - The type number of the aircraft. (The type TYPE number of an aircraft specifies the type of aircraft being modeled such as a Boeing 727 or a McDonnell-Douglas DC-9. See table 5.)

GROUND CORRECTION (GRCORR) - The height of the ground between the aircraft and the transmitter (relative to zero Z reference). This value determines the location of the specular ground reflection point between the transmitter and the scattering aircraft. See section 2.1.2.2 for the method of determining this value.

The model contains a data base of aircraft types that are available for simulation. They are listed in table 5. Each aircraft is represented by a set of geometric parameters which specify the size and shape of the critical aircraft structures.

TABLE 5. AVAILABLE AIRCRAFT TYPE NUMBERS AND DESCRIPTION

Type Number	Description
1	747
2	707-320B
3	727
4	DC10
5	C124
6	Convair 880
7	Hastings
8	Water tower
9	Small diameter pipe
10	n/a
11	C5A
12	C141

3.2.3.5 Section 4 (Scattering Buildings) Description.

Section 4 contains information on scattering building surfaces. The answer to the first question sets a flag to determine if building reflections are to be simulated.

ID NO. (##) - Two-character identification for each scattering building.

ENDPOINTS - The X and Y coordinates of the left corner and right corner of the building, the left corner specified first. To maintain consistency with building tilt angle, the "left" corner is defined as the corner with the smaller X coordinate. If the X coordinates of the left and right corners are equal, the "left" corner is the one with the larger Y coordinate.

ELEVATION (ELEV) - The height of the bottom of the building above the zero Z reference.

HEIGHT (HGT) - The height of the building plate, bottom to top.

TILT (TLT) - The tilt angle of the building plate measured down from the zenith, specified in degrees. It is measured as positive if the tilt is in the

counterclockwise direction (as viewed from the origin) and is negative otherwise. Where the plate is parallel to the Y axis, the same principle applies as viewed into the negative Y axis.

GROUND CORRECTION (GRCORR) - The height of the ground between the building and the transmitter (relative to the zero Z reference). This value determines the location of the specular ground reflection point between the transmitter and the scattering building (see section 2.1.2.2).

COMPOSITION (CMP) - A character string indicating the composition of the building surface to allow the assignment of a representative dielectric constant. The program contains a library of dielectric constants for a variety of materials which may appear as reflecting surfaces in the airport environment. Table 6 lists the contents of this library.

3.2.3.6 Section 5 (Rectangular Ground) Description.

Section 5 contains data on up to ten tilted rectangular ground plates. The answer to the first question sets a flag to determine if rectangular ground plates are to be simulated. Note: Section 2 flags also affect the execution of this option.

ID NO. (##) - Two-character identification for each rectangular element.

LOCATION - The X, Y, and Z coordinates (VALU) of three corners of the rectangle, listed with the X coordinates in increasing order of magnitude.

DIELECTRIC CONSTANT - The real (DCREAL) and imaginary (DCIMAG) parts of the dielectric constant to be used with this surface element. Table 6 may be used as a reference.

ROUGHNESS FACTOR (ROUGHN) - The rms roughness height to be used with this surface element.

SURFACE FLAG (SF) - The ground reflection processing normally computes a primary specular ground reflection from only one of all the available surfaces. This surface flag, when set to 1, selects the focusing ground option which will cause a specular ground reflection to be computed for the flagged surface in addition to the primary specular reflection.

TABLE 6. DIELECTRIC CONSTANT VALUES FOR SCATTERING BUILDINGS

Composition	Name (CMP)	Dielectric Constant Real	Dielectric Constant Imaginary
Concrete	CONCR	10.0	-9.0
Smooth Metal	METAL	1.0	-1.0E8
Glass	GLASS	6.0	-0.042
Marble	MARBL	8.7	-0.2
Asphalts	ASPHA	2.6	-0.016
Plastics	PLAST	3.0	-0.09
Bakelite	BAKEL	4.5	-0.1
Laminated Fiberglass	FIBER	4.4	-0.13
Polyvinyl Chloride	POLYV	3.0	-0.15
Formica	FORMI	4.0	-0.1
Sandy Dry Soil	SSDRY	2.5	-0.016
Sandy Soil, 20% Moisture	SS20%	20.0	-2.6
Loamy Dry Soil	LSDRY	2.4	-0.0027
Loamy Soil, 15% Moisture	LS15%	20.0	-2.4
Clay Dry Soil	CSDRY	2.27	-0.034
Clay Soil, 20% Moisture	CS20%	11.3	-2.8
Rocky Soil 10% Moisture	RS20%	30.0	-0.06
Dry Turf, Short Grass	DTWSG	3.0	-0.9
Wet Turf, Short Grass	WTWSG	6.0	-1.8
City Industrial Area	CITYI	5.0	-0.02
Fresh Water	FRESH	80.0	-0.18
Sea Water	SEA	80.0	-54.0
Fresh Snow	SNOW	1.2	-1.3
Ice	ICE	3.2	-0.0029

3.2.3.7 Section 6 (Triangular Ground) Description.

Section 6 contains data on up to ten tilted triangular ground plates. The answer to the first question sets a flag to determine if triangular ground plates are to be simulated. Note: Section 2 flags also affect the execution of this option.

ID NO. (##) - Two-character identification for each triangular element.

LOCATION - The X, Y, and Z coordinates (VALU) of the three corners of the triangle, listed with the X coordinates in increasing order of magnitude.

DIELECTRIC CONSTANT - The real (DCREAL) and imaginary (DCIMAG) parts of the dielectric constant to be used with this surface element. Table 6 may be used as reference.

ROUGHNESS FACTOR (ROUGHN) - The rms roughness height to be used with this surface element.

SURFACE FLAG - The ground reflection processing normally (SF) computes a primary specular ground reflection from only one of all the available surfaces. This surface flag, when set to 1, selects the focusing ground option which will cause a specular ground reflection to be computed for the flagged surface in addition to the primary specular reflection.

3.2.3.8 Section 7 (Diffuse Ground) Description.

Section 7 contains information for simulating diffuse ground reflections. The answer to the first question sets a flag to determine if diffuse reflections are to be simulated.

ROUGHNESS HEIGHT (SIGH) - The Gaussian height distribution.

CORRELATION LENGTH (SIGL) - The Gaussian correlation coefficient; the rms distance between peaks.

Different diffuse reflection parameters are used for each of the three subsystems - azimuth, elevation, and DME/P.

3.2.3.9 Section 8 (Shadowing Aircraft) Description.

Section 8 contains data on aircraft as shadowing obstacles. The answer to the first question sets a flag to determine if aircraft shadowing is to be simulated. Independent ground reflections will not be calculated if this flag is set.

ID NO. (##) - Two-character identification for each shadowing aircraft.

LOCATION - The starting and ending X, Y, and Z coordinates (VALU) of the aircraft. If the distance between the start and stop points is less than the length of the aircraft, the aircraft is considered stationary at the starting point. For a stationary aircraft, the start point is the center of the fuselage. The stop point is placed in the direction of the aircraft nose. The distance, which should be less than the length of the aircraft, cannot be zero. If the distance between the start and stop points is greater than the length of the aircraft, these coordinates define a moving shadowing aircraft.

VELOCITY (VEL) - The aircraft velocity, in units per second (zero if the aircraft is stationary).

ANGLE (ANG) - The pitch angle of the aircraft in degrees.

TYPE (AT) - The aircraft type (see table 5 and section 3.2.3.4)

3.2.3.10 Section 9 (Shadowing Buildings) Description.

Section 9 contains data on buildings as shadowing obstacles. The answer to the first question sets a flag to determine if building shadowing is to be simulated. Independent ground reflections will not be calculated if this flag is set.

ID NO. (##) - Two-character identification for each shadowing building.

LOCATION - The X and Y coordinates of the left and right corners of the shadowing building plate, the left corner specified first.

ELEVATION (ELV) - The elevation (height) of the bottom of the building above the zero Z reference.

HEIGHT (HGT) - The height of the building (bottom to top).

3.2.3.11 Section 10 (Runway Hump Shadowing) Description.

Section 10 contains data for a runway hump. The answer to the first question sets a flag to request that the runway hump shadowing be simulated. Even when this question is answered YES, the flag is ignored (assumed NO) if shadowing by buildings or aircraft is being simulated. If runway hump shadowing is simulated, independent ground reflections (both default ground and ground plates) will not be computed when the hump is within the transmitter-to-aircraft line-of-sight.

LOCATION - The X and Z coordinates of the front, center and back of the hump, in that order. The hump is on runway centerline, and the front and back coordinates should be symmetrically placed on either side of, and below, the peak.

3.2.3.12 Section 11 (Runway Profile) Description.

Section 11 contains runway profile information. The points in this section define the runway profile.

POINT NO. (##) - Two-character identifier for each point, beginning from stop end.

LOCATION - Coordinates (XP, YP, ZP) of each runway profile point. Typically, the profile is defined along centerline and, therefore, the Y coordinate of each point will be zero.

3.2.3.13 Section 12 (Flightpath) Description.

Section 12 specifies the flightpath. Six flightpaths are available:

1 - Measured
2 - Distance
3 - Orbit
4 - Radial
5 - Segmented
6 - Straight

Flightpaths 2 to 6 are specified by parameter values appearing here in the input file. Flightpath 1 is specified by a set of coordinate points read from a separate input file. Typically, the measured flightpath is created from actual flight data.

3.2.3.13.1 Measured Flightpath.

A measured flightpath is one taken from the file of an actual (or computed) run which contains all the information necessary for the simulation flightpath. The flightpath is read by the propagation model program (BMLST) from a file containing a title record followed by records of time (in seconds) and X, Y, Z coordinates (in units), using the FORTRAN format 4(1X,F12.3). Only these four values will be read for each record following the title. Sampling increment and velocity are computed from the time/position data. To be consistent with PFE and CMN filtering, measured flightpaths must be defined at a data rate of 5 Hz (i.e., five samples per second). Data from measured flightpaths are normally plotted with the same X axis as their equivalent flightpath. The default is distance from azimuth antenna in nmi.

The name of the measured flightpath file is entered interactively during BMLST. The following data are required in the formatted input file to simulate a measured flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: measured.

3.2.3.13.2 Distance Flightpath.

A distance flightpath is one in which the simulated aircraft follows straight segments between defined waypoints, at the segment velocity, in the order in which the waypoints are entered. Distance flightpath data are normally plotted with the X axis as distance along flightpath in feet.

The following data are required in the formatted input file to simulate a distance flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: distance.

A distance flightpath is defined by 2 to 36 waypoints (up to 35 segments) each of which requires the following:

ID NO. (##) - Two-character identification for each flightpath waypoint.

COORDINATES - The three coordinates needed to specify each waypoint in the model coordinate system. The first waypoint is usually the farthest from the origin.

VELOCITY - The aircraft velocity in units/second for the segment beginning with this waypoint.

INCREMENT - The sampling increment distance, in feet, for the segment beginning with this waypoint.

3.2.3.13.3 Orbit Flightpath.

An orbit flightpath is a flightpath at a constant altitude and a constant range from the DME/P between two azimuth angles. That is, orbits are arcs of a circle centered on the DME/P antenna between the azimuth coverage limits. Orbit flightpath data are plotted using azimuth angle in degrees as the X axis.

The following data are required in the formatted input file for simulating an orbit flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: orbit.

VELOCITY - The aircraft velocity in units/second.

INCREMENT - The sampling increment distance in units. This must be specified to maintain the data rate of 5 Hz assumed by BMLSR. Usually, it is 1/5 of the velocity, yielding a data rate (interval) of 0.2 second.

DATA RATE - The data rate should always be 0.2 (5 Hz).

RADIUS - The radius, in nmi, from the DME/P.

ELEVATION - The elevation (altitude) of the orbital flightpath, in units above the zero Z reference.

3.2.3.13.4 Radial Flightpath.

A radial flightpath is a straight-in approach at a constant altitude (height). Radial flightpath data are plotted with the X axis as distance in nmi from the azimuth antenna.

The following data are required in the formatted input file to simulate a radial flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: radial.

VELOCITY - The aircraft velocity in units/second.

INCREMENT - The sampling increment distance in units. This must be specified to maintain the data rate of 5 Hz assumed by BMLSR. Usually, it is 1/5 of the velocity, yielding a data rate (interval) of 0.2 second.

DATA RATE - The data rate should always be 0.2 (5 Hz).

ANGLE - The radial azimuth angle along which the flight is to take place.

START DISTANCE - The distance, in nmi, from the DME/P to the flightpath start point.

END DISTANCE - The distance, in nmi, from the DME/P to the flightpath end point.

ELEVATION - The elevation (altitude) of the flightpath, in units above the zero Z reference.

3.2.3.13.5 Segmented Flightpath.

A segmented flightpath is a flightpath between waypoints. The simulated aircraft follows a straight path between the defined waypoints, at the segment velocity, in the order in which the waypoints are entered. Segmented flightpath data are normally plotted with the X axis as distance from threshold in nmi.

The following data are required in the formatted input file to simulate a segmented flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: segmented.

A segmented flightpath is defined by 2 to 36 waypoints (up to 35 segments) each of which requires the following:

ID NO. (##) - Two-character identification for each flightpath waypoint.

COORDINATES - The X, Y, and Z coordinates needed to specify each waypoint in the model coordinate system. The first waypoint is usually the farthest from the origin.

VELOCITY - The aircraft velocity in units/second for the segment beginning with this waypoint.

INCREMENT - The sampling increment distance, in units, for the segment beginning with this waypoint.

3.2.3.13.6 Straight Flightpath.

A straight flightpath is a flightpath along the centerline from the final approach fix to the datum at the minimum glidepath angle. Straight flightpath data are normally plotted with the X axis as distance from threshold in nmi.

The following data are required in the formatted input file to simulate a straight flightpath:

FAF - Location in nmi from threshold of the final approach fix.

DATUM - The X, Y, and Z coordinates of the point on runway centerline directly opposite the elevation antenna site.

TYPE - The type of flightpath: straight.

VELOCITY - The aircraft velocity in units/second.

INCREMENT - The sampling increment distance in units. This must be specified to maintain the data rate of 5 Hz assumed by BMLSR. Usually, it is 1/5 of the velocity, yielding a data rate (interval) of 0.2 seconds.

DATA RATE - The data rate should always be 0.2 (5 Hz).

3.2.3.14 Section 13 (Plot Limits) Description.

Section 13 specifies the plot scale limits for the flightpath and airport layout plots. Three flightpath plots, X versus Y, X versus Z, and distance versus Z, are available. For each plot, a minimum value and an increment value (units per division) are required for both X and Y plot axes. The distance versus Z plot should employ the same X axis scale as the multipath plots to facilitate comparison.

3.2.3.15 Section 14 (Angle Systems Plot Limits) Description.

Section 14 specifies the plot scale limits for the multipath and error plots for the angle systems, azimuth and elevation. Multipath plots available include both scattering (multipath/direct ratio in dB) and shadowing (direct amplitude only in dB). If a scattering plot is requested, a separation angle plot is produced automatically. Error plots include raw error (static and dynamic) and filtered error (PFE and CMN). Plot limits, specified for each plot axis, are the minimum value and increment (units per division).

3.2.3.16 Section 15 (DME/P Plot Limits) Description.

Section 15 specifies the plot scale limits for the multipath and error plots for the DME/P subsystem. The options are the same as those for angle systems except that a time delay plot replaces the separation angle plot.

3.3 EXECUTION GUIDES.

This section contains execution guides for the four programs BMLST, BPLOTT, BMLSR, and BPLOTR that make up the MLS mathematical model.

Prompts appear in uppercase and bold type. Valid responses and echoed information appear in lowercase. Comments in the text are indicated by square brackets [ ]. These are not part of the program code.

a. Prompts are written to the logical output unit ISOU and responses are read from logical input unit ISIU initialized in the user written site initialization subroutine, SINIT, which must be linked with each of the four model programs.

b. <CR> indicates a carriage return entered by the user by pressing the data entry key (usually RETURN or ENTER) after the response is entered.

c. Any prompts requiring a yes or no answer will accept upper or lower case Y, N, YES, or NO. If an invalid answer is given, a prompt of

REENTER (Y/N):

is written until a valid response is obtained.

3.3.1 Propagation Model (BMLST) Execution Guide.

Data are read from logical unit PID (formatted input file) and written to logical units RID (input to system model) and PPID (input to plotting program) initialized in SINIT.

To run BMLST:

Enter the operating system commands necessary to begin execution of the program BMLST.

Prompts appear as follows:

ENTER FULL NAME OF PROPAGATION MODEL INPUT DATA FILE pid
(UP TO 40 CHARACTERS):

full_input_file_name <CR>

[or]

<CR>

ENTER FULL NAME OF PROPAGATION MODEL OUTPUT DATA FILE ppid
-- PLOT FILE
(UP TO 40 CHARACTERS):

full_plot_file_name <CR>

[or]

<CR>

ENTER FULL NAME OF PROPAGATION MODEL OUTPUT DATA FILE rid
-- INPUT TO SYSTEM MODEL
(UP TO 40 CHARACTERS):

full_system_file_name <CR>

[or]

<CR>

[File numbers with corresponding file names echo to unit ISOU.]

FILE: pid **NAME:** full_input_file_name
FILE: ppid **NAME:** full_plot_file_name
FILE: rid **NAME:** full_system_file_name

[If the user entered no file name, the echo will show **SYSTEM DEFAULT** where the file name appears. The program assumes that the operating system has a default file naming protocol to assign file names when none are given. If no naming protocol is available, the program will terminate abnormally when an attempt is made to open the first file without a name.]

ARE THESE FILE NAMES CORRECT?

no <CR>

ENTER NUMBER OF FILE WHOSE NAME MUST BE MODIFIED:

nn <CR>

[If "nn" is not PID, PPID, or RID, a message of **INVALID FILE NUMBER** appears, and the above prompt is displayed until a valid file number is obtained.]

[The prompt (see earlier prompts) for the file associated with the file number indicated by "nn" is displayed and a new file name is entered by the user. The flow of the prompts resumes from the echoing of the file names and numbers to unit ISOU. This sequence is repeated until the user enters a response indicating that the file names are correct.]

[or]

yes <CR>

[At this point the program opens the designated files using the user written subroutine SOPEN which must be linked with each of the four programs. The input data file, PID, is read by BMLST. For each section read, a line is written to unit ISOU to inform the user. Any error messages generated for an input file section will also be written to unit ISOU.]

DO YOU WANT TO SEE A COPY OF THE INPUT DATA?

yes <CR>

[A copy of the input data is written to unit ISOU.]

[or]

no <CR>

[The program writes site name, address, run time, and run date (initialized in SINIT) to the output files RID and PPID. A copy of the complete input data file is written to each output file.]

[If a measured flightpath was indicated in section 12 of the input file...]

ENTER NAME OF FILE CONTAINING MEASURED FLIGHTPATH DATA. (UP TO 40 CHARACTERS)

full_file_name <CR>

FILE: mfid **NAME:** full_measured_flightpath_file_name

IS THIS FILE NAME CORRECT?

yes <CR>

[or]

no <CR>

[If the answer is no, the user is given the opportunity to reenter the measured flightpath file name, as with other file names. When a valid file name is entered, the file is opened with a call to SOPEN. If the measured flightpath file is empty, the message]

EMPTY MEASURED FLIGHTPATH DATA FILE.

[is displayed and execution stops. If the file is valid, the title is read and echoed to ISOU for user information. The interactive section of BMLST continues.]

PROCESS AZIMUTH DATA?

yes <CR>

[or]

no <CR>

PROCESS ELEVATION DATA?

yes <CR>

[or]

no <CR>

PROCESS DME/P UPLINK DATA?

yes <CR>

[or]

no <CR>

PROCESS DME/P DOWNLINK DATA?

yes <CR>

[or]

no <CR>

PERTURBATION SMOOTHING?

yes <CR>

[or]

no <CR>

User entry ends here. The program writes information messages to ISOU indicating the program being run, the time when program processing began (initialized in SINIT), and the major processing options chosen (written from the appropriate subroutine, when called). Flags indicating systems requested (AZ, EL, DME/P) are written to the output file PPID. System flags and a perturbation smoothing flag are written to the output file RID.

<u>3.3.2 Propagation Model Plotting Program (BPLOTT) Execution Guide</u>.

Data are read from logical unit PPID and written to logical unit PROD (initialized in SINIT).

To run BPLOTT:

Enter the operating system commands necessary to begin execution of the program BPLOTT.

Prompts will appear as follows:

ENTER FULL NAME OF PROPAGATION MODEL PLOTTING INPUT DATA FILE ppid **(UP TO 40 CHARACTERS):**

full_plot_input_file_name <CR>

[or]

<CR>

[The file number with corresponding file name is echoed to unit ISOU.]

FILE: ppid **NAME:** full_plot_input_file_name

[If the user entered no file name, the echo will show **SYSTEM DEFAULT** where the file name appears. The program assumes that the system has a default file naming protocol to assign file names when none are given. If no naming protocol is available, the program will terminate abnormally when an attempt is made to open the first file without a name.]

IS THIS FILE NAME CORRECT?

no <CR>

[The prompt (see earlier prompt) for the file is displayed, and a new file name is entered by the user. The flow of the prompts resumes from the echoing of the file name and number to unit ISOU. This sequence is repeated until the user enters a response indicating the name is correct.]

[or]

yes <CR>

[At this point the program opens the file (with a call to SOPEN) and reads the site name, address, run time, date of propagation model processing, and the input data file portion of PPID. When each input file section is read, a line is written to unit ISOU to inform the user. Any error messages generated for a section will also be written to unit ISOU. Flags indicating which systems exist, which are found after "END DATA," are read from unit PPID.]

DO YOU WANT PLOT TABLES?

yes <CR>

[Information describing the various obstacles and antennas is written in table format.]

[or]

no <CR>

DO YOU WANT FLIGHTPATH PLOTS?

yes <CR>

[Three views of the flightpath are plotted: (1) X versus Y coordinates, (2) X versus Z coordinates, and (3) distance versus Z coordinates.]

[or]

no <CR>

DO YOU WANT AIRPORT PLOTS?

yes <CR>

[A map of the airport showing runway, transmitters, and obstacles defined in the input file is plotted.]

[or]

no <CR>

DO YOU WANT MULTIPATH PLOTS?

yes <CR>

[This enables plots of the multipath/direct ratio in decibels and the separation angle in degrees (time delay in nanoseconds for DME/P) against flightpath position for each of the six highest sources of multipath.]

[or]

no <CR>

DO YOU WANT SHADOWING PLOTS?

yes <CR>

[This enables plots of the amplitude of the direct signal in decibels against the flightpath position.]

[or]

no <CR>

[If plot tables, airport map, multipath plots, or shadowing plots were selected by the user, the following section of prompts is written to unit ISOU.]

DATA EXISTS FOR THE FOLLOWING SYSTEM(S):

AZIMUTH
ELEVATION
DME/P UPLINK
DME/P DOWNLINK

[The list printed is dependent on the systems that were processed by BMLST. Flags in PPID after the words END DATA indicate which systems are available for plotting.]

PROCESS AZIMUTH DATA?

[This prompt appears only if the azimuth data flag in PPID is set.]

yes <CR>

[or]

no <CR>

PROCESS ELEVATION DATA?

[This prompt appears only if the elevation data flag in PPID is set.]

yes <CR>

[or]

no <CR>

PROCESS DME/P UPLINK DATA?

[This prompt appears only if the DME/P uplink data flag in PPID is set.]

yes <CR>

[or]

no <CR>

PROCESS DME/P DOWNLINK DATA?

[This prompt appears only if the DME/P downlink data flag in PPID is set.]

yes <CR>

[or]

no <CR>

User entry as determined by BPLOTT ends here. However, other user entry may be necessary when creating the actual plots if required by the user written graphics interface subroutines.

3.3.3 System Model (BMLSR) Execution Guide.

Data are read from logical unit RID and written to logical units PRID and RDO (initialized in SINIT).

To run BMLSR:

Enter the operating system commands necessary to begin execution of the program BMLSR.

Prompts will appear as follows:

ENTER FULL NAME OF SYSTEM MODEL INPUT DATA FILE rid **(UP TO 40 CHARACTERS):**

full_input_file_name <CR>

[or]

<CR>

ENTER FULL NAME OF SYSTEM MODEL OUTPUT DATA FILE prid **-PLOT FILE (UP TO 40 CHARACTERS):**

full_plot_file_name <CR>

[or]

<CR>

DO YOU WANT CONFIDENCE COUNTER AND FLAG INFO?

yes <CR>

ENTER FULL NAME OF SYSTEM MODEL OUTPUT DATA FILE rdo **- FLAGS AND CONFIDENCE COUNTER DATA (UP TO 40 CHARACTERS):**

full_flag_file_name <CR>

[or]

<CR>

[or]

no <CR>

[File numbers with corresponding file names are echoed to unit ISOU.]

FILE: rid **NAME:** full_input_file_name
FILE: prid **NAME:** full_plot_file_name
FILE: rdo **NAME:** full_flag_file_name

[RDO appears only if the user requested confidence counter and flag info. If the user enters no file name, the echo will show **SYSTEM DEFAULT** where the file name appears. This assumes that the system has a default file naming protocol to assign file names when none are given. If no naming protocol is available, the program will terminate abnormally when an attempt is made to open the first file without a name.]

ARE THESE FILE NAMES CORRECT?

no <CR>

ENTER NUMBER OF FILE WHOSE NAME MUST BE MODIFIED:

nn <CR>

[If "nn" is not RID, PRID, or RDO, a message of **INVALID FILE NUMBER** appears and the above prompt is displayed until a valid file number is obtained.]

[The prompt (see earlier prompts) for the file associated with the file number indicated by "nn" is displayed, and a new file name is entered by the user. The flow of the prompts resumes from the echoing of the file names and numbers to unit ISOU. This sequence is repeated until the user enters a response indicating that the file names are correct.]

[or]

yes <CR>

[At this point, the program opens the files with a call to SOPEN and reads the input data file portion of RID. For each section read, a line is written to unit ISOU to inform the user. Any error messages generated for a section will also be written to unit ISOU. Flags indicating which systems exist are read from RID after the words END DATA.]

DO YOU WANT TO SEE A COPY OF THE INPUT DATA?

yes <CR>

[A copy of the input data file is written to unit ISOU.]

[or]

no <CR>

[The program writes site name, address, run time of BMLSR, run date of BMLSR (initialized in SINIT) and a copy of the input file (along with BMLST user name, address, run time and date) to the output file PRID.]

DATA EXISTS FOR THE FOLLOWING SYSTEM(S):

AZIMUTH
ELEVATION
DME/P UPLINK
DME/P DOWNLINK

[The list printed is dependent on the systems that were processed by BMLST. Flags in RID after the words END DATA indicate which systems are available for processing.]

PROCESS AZIMUTH DATA?

[This prompt appears only if the azimuth data flag in RID is set.]

yes <CR>

[or]

no <CR>

PROCESS ELEVATION DATA?

[This prompt appears only if the elevation data flag in RID is set.]

yes <CR>

[or]

no <CR>

PROCESS DME/P UPLINK DATA?

[This prompt appears only if the DME/P uplink data flag in RID is set.]

yes <CR>

[or]

no <CR>

PROCESS DME/P DOWNLINK DATA?

[This prompt appears only if the DME/P downlink data flag in RID is set.]

yes <CR>

[or]

no <CR>

PERTURBATION SMOOTHING DATA POINTS EXIST

PERTURBATION SMOOTHING?

[These prompts appear only if the perturbation smoothing data flag in RID is set.]

yes <CR>

[or]

no <CR>

[Flags identifying the systems being processed (azimuth, elevation, DME/P) and perturbation smoothing flags are written to the output file PRID.]

MAKE VELOCITY AND ACCELERATION CORRECTIONS FOR EACH SCAN?

yes <CR>

[or]

no <CR>

SIMULATE SPLIT GATE RECEIVER PROCESSING?

yes <CR>

[Split gate receiver processing will be performed.]

[or]

no <CR>

[Dwell gate receiver processing will be performed. A flag indicating the selected receiver processing algorithm is written to PRID.]

User entry ends here. A message is displayed indicating the time when BMLSR begins processing (as determined by SINIT).

3.3.4 System Model Plotting Program (BPLOTR) Execution Guide.

Data are read from logical unit PRID and written to logical unit PROD (initialized in SINIT).

To run BPLOTR:

Enter the operating system commands necessary to begin execution of the program BPLOTR.

Prompts will appear as follows:

ENTER FULL NAME OF SYSTEM MODEL PLOTTING INPUT DATA FILE prid **(UP TO 40 CHARACTERS):**

full_plot_input_file_name <CR>

[or]

<CR>

[The file number and file name are echoed to unit ISOU.]

FILE: prid **NAME:** full_plot_input_file_name

[If the user enters no file name, the echo will show **SYSTEM DEFAULT** where the file name appears. This assumes that the system has a default file naming protocol to assign file names when none are given. If no naming protocol is available, the program will terminate abnormally when an attempt is made to open the first file without a name.]

IS THIS FILE NAME CORRECT?

no <CR>

[The prompt (see earlier prompt) for the file is displayed and a new file name is entered by the user. The flow of the prompts resumes from the echoing of the file name and number to unit ISOU. This sequence is repeated until the user enters a response indicating that the file name is correct.]

[or]

yes <CR>

[At this point the program opens the file (with a call to SOPEN) and reads the site name, address, run time, date of system model processing, and the input data file portion of PRID. When each input file section is read, a line is written to unit ISOU to inform the user. Any error messages generated for a section will also be written to unit ISOU. Flags indicating which systems exist, found after "END DATA," are read from unit PRID.]

DATA EXISTS FOR THE FOLLOWING SYSTEM(S):

AZIMUTH
ELEVATION
DME/P UPLINK
[or]
DME/P DOWNLINK
[or]
DME/P MEAN

[The list printed is dependent on the systems that were processed by BMLSR. Flags in PRID after the words END DATA indicate which systems are available for processing. If both DME/P uplink and downlink have been processed by BMLSR, BPLOTR will plot the mean errors of the two systems.]

PROCESS AZIMUTH DATA?

[This prompt appears only if the azimuth data flag in PRID is set.]

yes <CR>

[or]

no <CR>

PROCESS ELEVATION DATA?

[This prompt appears only if the elevation data flag in PRID is set.]

yes <CR>

[or]

no <CR>

PROCESS DME/P UPLINK DATA?

[This prompt appears only if the DME/P uplink data flag in PRID is set but not the DME/P downlink data flag.]

yes <CR>

[or]

no <CR>

PROCESS DME/P DOWNLINK DATA?

[This prompt appears only if the DME/P downlink data flag in PRID is set but not the DME/P uplink data flag.]

yes <CR>

[or]

no <CR>

PROCESS DME/P MEAN DATA?

[This prompt appears only if both the DME/P uplink and DME/P downlink data flags in PRID are set.]

yes <CR>

[or]

no <CR>

PERTURBATION SMOOTHING DATA POINTS EXIST

PERTURBATION SMOOTHING?

[These prompts appear only if the perturbation smoothing data flag in PRID is set.]

yes <CR>

[or]

no <CR>

[The next section of prompts appears only if azimuth data exist in the input file and the user has selected to plot them.]

AZIMUTH PLOTTING:

PLOT STATIC ERRORS?

yes <CR>

[or]

no <CR>

PLOT DYNAMIC ERRORS?

yes <CR>

[or]

no <CR>

PLOT PFE ERRORS?

yes <CR>

[or]

no <CR>

PLOT CMN ERRORS?

yes <CR>

[or]

no <CR>

[The next section of prompts appears only if elevation data exist in the input file and the user has selected to plot them.]

ELEVATION PLOTTING:

PLOT STATIC ERRORS?

yes <CR>

[or]

no <CR>

PLOT DYNAMIC ERRORS?

yes <CR>

[or]

no <CR>

PLOT PFE ERRORS?

yes <CR>

[or]

no <CR>

PLOT CMN ERRORS?

yes <CR>

[or]

no <CR>

[The next section of prompts appears only if DME/P data exist in the input file and the user selected to plot them.]

DME/P PLOTTING:

PLOT STATIC ERRORS?

yes <CR>

[or]

no <CR>

PLOT DYNAMIC ERRORS

yes <CR>

[or]

no <CR>

PLOT PFE ERRORS?

yes <CR>

[or]

no <CR>

PLOT CMN ERRORS?

yes <CR>

[or]

no <CR>

User entry as determined by BPLOTR ends here. However, other user entry may be necessary when creating the actual plots if required by the user written graphics interface subroutines.

4. MATHEMATICAL MODEL OUTPUT.

The results of a simulation performed with the MLS mathematical model are written in numeric form to ASCII output files. One

output file, logical unit RID, communicates the results of the propagation model (BMLST) to the system model (BMLSR). The other output files (units PPID and PRID) provide the output of the propagation and system simulations, respectively, to the associated plotting programs. The results of the simulation are more easily interpreted when presented in graphic form. This section discusses the tables and plots which provide graphic output to the user from the two plotting programs. It also describes the numeric files which transfer the data from one program to the other.

Examples for all the tables and figures discussed in this section appear in the appendix of this volume. These examples are the model output from a simulation of Los Angles International Airport. The input file for this scenario is provided in table A-1.

4.1 GRAPHIC OUTPUT FROM PROPAGATION MODEL.

Output from the propagation model plotting program BPLOTT is produced in both table and plot form. The output echoes the input parameters for user verification and plots the results of the propagation simulation for analysis.

4.1.1 Plot Tables.

The primary purpose of the tables is to echo the input data. Toward this end, the tables present title information, transmitter parameters, flightpath coordinates, and the input parameters for all scattering and shadowing obstacles defined in the input file. This associates the input parameters with the graphic output and enables the user to verify the correctness of the scenario definition. Examples of the output tables are provided in the appendix: tables A-2 through A-4.

The plot tables also provide diagnostic information in the multipath amplitude rankings. These list each scattering obstacle defined for the scenario, the amplitude of the strongest multipath reflection from that obstacle along the entire flightpath (in decibels relative to the direct wave), and the X axis reference of the point at which the reflection reached the receiver. Each obstacle is ranked relative to the other obstacles based on the amplitude of its multipath reflection. Only scattering aircraft, buildings, and ground are listed. A table is produced for each transmitter as illustrated in the appendix, tables A-5 through A-8.

4.1.2 Flightpath Plots.

The flightpath is graphically presented in three different views. Figure A-1 in the appendix shows the X-Y flightpath plot which plots the X coordinate against the Y coordinate (in feet). Figure A-2 in the appendix illustrates the plot of the X coordinate against the Z coordinate (in feet). Figure A-3 in the appendix shows the Z coordinate in feet plotted against the distance. The

distance reference and unit are determined by the flightpath type and may be distance from runway threshold in nautical miles (straight or segmented flightpath), distance from azimuth antenna in nautical miles (radial or measured flightpath), distance along flightpath in feet (distance flightpath), or azimuth angle in degrees (orbit flightpath). The X-Y and X-Z plots approximate the flightpath in three dimensions. The Z-distance plot facilitates comparison of the flightpath with scattering and shadowing plot data.

4.1.3 Airport Map.

The parameters specifying the locations of the runway, transmitters, and multipath obstacles are listed in tables A-2 through A-4. The proper assignment of these parameters can be confirmed by examining a plot of the positions of the transmitters and obstacles relative to the runway. An airport map or plan view of the airport is shown in figure A-4. The example depicted is for a scenario at Los Angles International Airport, runway 24R, with 12 obstacles, specifically, 4 aircraft, 7 buildings, and a runway hump.

Tilted ground plates are also drawn in outline on the airport map. The rectangles are labeled "R" and the triangles are labeled "T" at their corners to make them more discernible.

4.1.4 Multipath Plots.

The propagation model calculates the signal levels at the aircraft of all the important multipath signals from the azimuth, elevation, and DME/P uplink transmitters. The signal level at the DME/P transponder is calculated for the multipath signals from the DME/P airborne interrogator (downlink). This is done for each position of the aircraft on its flightpath. The relative rankings of scattering obstacles as sources of multipath are given in tabular form for the azimuth, elevation, DME/P uplink, and DME/P downlink signals (as discussed above). These data are also presented in graphic form in the multipath plots. Multipath data are plotted for the six scattering obstacles producing the strongest multipath interference. The relative signal strength of each multipath signal, expressed as the ratio of multipath to direct signal in decibels, is plotted as a function of the receiver position. Each obstacle (six highest sources only) is represented by a different symbol so that the sources of multipath can be distinguished. These symbols are defined in the user written graphics interface subroutines.

The propagation model also determines the separation angle between the direct beam and each multipath for the azimuth and elevation systems. This is a significant parameter for scenario analysis since the receiver can easily distinguish (and reject) any multipath reflection that is out-of-beam. A reflection is

considered to be out-of-beam if the angle between the direct signal and the reflected signal, measured at the transmitter, is greater than approximately 1.7 transmitter beam widths. In-beam multipath, a reflection that is less than 1.7 beam widths from the direct signal, can cause significant errors at the receiver and is a major concern for MLS site analysis. The separation angle for each multipath reflection shown on the multipath/direct signal ratio plots discussed above is plotted against receiver position to enable analysis of the possible impact of multipath reflections.

A similar process occurs for the DME/P system. That is, the shape of the direct received signal is affected by multipath reflections. This effect will only be a problem, however, if the reflected signal arrives too soon after the direct signal. A time delay of approximately 300 nanoseconds is a useful rule-of-thumb to determine the significance of the effects from reflecting obstacles on the ability of the DME/P to determine range. Therefore, the DME/P multipath/direct signal plots are accompanied by a time delay plot that shows the time delay for each multipath source plotted against receiver position.

Since both the amplitude and spatial location (or time delay) of a multipath signal are necessary for determining its effect on the ability of the receiver to provide accurate guidance information, both a multipath/direct amplitude plot and a separation angle (or time delay) plot are produced when multipath plots are requested by the user.

Multipath amplitude, separation, and time delay plots for the Los Angeles scenario are illustrated in the appendix by figures A-5 through A-12.

4.1.5 Shadowing Plots.

Buildings, aircraft, and a runway hump may shadow or block the transmitted signals at some points on the flightpath. These effects are shown in plots of the amplitude of the direct signal as a function of receiver position. Figures A-13 through A-16 in the appendix illustrate shadowing plots for the azimuth, elevation, DME/P uplink, and DME/P downlink signals, respectively. Note that the mathematical model assumes that a runway hump will not affect the elevation signal since, with the standard elevation siting, a runway hump is not within the line-of-sight from the elevation transmitter to the aircraft receiver.

4.2 GRAPHIC OUTPUT FROM SYSTEM MODEL.

The system model generates plots of the errors for each system (azimuth, elevation, DME/P uplink or downlink or mean). Error data are presented in four formats: static errors, dynamic errors, PFE filtered errors, and CMN filtered errors. Each set of errors is plotted as a function of receiver position. Each system is plotted

separately, as requested by the user. A complete set of system model plots for the example scenario is provided in the appendix, figures A-17 through A-28.

4.2.1 Static Error Plot.

The static error plot shows the simulated receiver error, in degrees for the angle systems or feet for the DME/P, against the position of the receiver for each flightpath point. Each flightpath point is considered as a separate event without reference to aircraft direction or velocity.

4.2.2 Dynamic Error Plot.

The dynamic error plot also shows the simulated receiver error in degrees for the angle systems, or feet for the DME/P, against the position of the receiver for each flightpath point. However, here the effects of any receiver filtering, slew rate limiting, and motion averaging are taken into consideration, and the points are connected in a continuous line.

4.2.3 PFE Error Plot.

For the PFE error plots, the error data are passed through a low-pass filter before being plotted against the receiver position. In addition to the error data, PFE tolerance limits based on FAA specifications are displayed on the plot so that the user can see whether or not the signal errors are out of tolerance at any point along the flightpath.

4.2.4 CMN Error Plot.

For the CMN error plots, the error data are passed through a high-pass filter (cascaded with a ten-radian cutoff low pass filter to simulate receiver output characteristics) before being plotted against the receiver position. In addition to the error data, CMN tolerance limits based on FAA specifications are displayed on the plot so that the user can see whether or not the signal errors are out of tolerance at any point along the flightpath.

4.3 OUTPUT FILES.

All input and output files for the MLS simulation programs are Fortran formatted (ASCII) files.

4.3.1 Unit RID.

RID is the logical unit associated with the file that transfers data between BMLST and BMLSR. That is, RID contains output from BMLST which becomes input to BMLSR. The contents of unit RID are significant to an understanding of the two simulation programs in the MLS mathematical model.

The first two records of RID contain the name and address of the organization performing the simulation and the date and time of execution of the propagation model. These parameters are initialized in the user written subroutine SINIT and are written to RID by the program BMLST.

Following these identifying records is a complete copy of the formatted input file. This allows the user to verify the input data and provides the input data to BMLSR.

The final record in the copy of the formatted input file consists of the words END DATA. Following this record are five integer flags indicating the transmitters that have been processed and whether or not the perturbation smoothing option was requested. The five integer flags can have values of either "0" (not requested) or "1" (requested) and represent, in order, azimuth, elevation, DME/P uplink, DME/P downlink, and perturbation smoothing. The flags are set by user responses in the interactive section of BMLST (see section 3.3.1).

The remainder of the RID file contains the multipath information required by BMLSR. The following information is written for each point on the flightpath (by subroutine WRTMLT):

a. IPSS - An integer indicating whether the flightpath point is a primary point (IPSS=1) or a point resulting from perturbation smoothing (IPSS=2 to 13).

b. INDX - An integer indicating the index number of the flightpath point for which data are being written.

c. XMTR - An integer indicating the current transmitter (1-azimuth, 2-elevation, 3-DME/P uplink, 4-DME/P downlink).

d. STOP - A logical flag which is false until the final flightpath point.

e. DIST - The distance of the current point along the flightpath, in feet.

f. RCVR - The X, Y, and Z coordinates of the current flightpath point (receiver position), in feet.

g. RVEL - The velocity vector, in feet per second in each coordinate direction (X,Y,Z), for the current flightpath point (receiver position).

h. NCOMP - An integer indicating the number of multipath components for the current flightpath point. The editing subroutine EDTMLT reduces this number to the 20 (or fewer) most significant multipath components. Therefore, after editing, NCOMP will not exceed 20. Before editing, a total of 147 are possible

including 1 direct wave, 1 ground reflection component, 40 building components (10 buildings with four ray paths for each), 40 aircraft fuselage components (10 aircraft with four ray paths for each), 40 aircraft tail components (10 aircraft with four ray paths for each), and 25 diffuse components.

For each multipath component that passes the editing subroutine, the following data are written:

a. AMP - The amplitude of the multipath component relative to the direct or no loss signal. The AMP value is used in the recreation of the signal envelope at the receiver when combined with the direct component and all other multipath components. The amplitude of the direct signal will also include shadowing effects, if any.

b. PHASE - The phase of the multipath component relative to the direct signal, measured in radians displacement from the direct. PHASE is used to combine the amplitudes of all components by separately summing the amplitude of each component times its phase sine and cosine. The resultant vector amplitude of these two sums is the envelope amplitude at that time.

c. AZ and EL - The two planar angles, measured in radians in the X-Y and X-Z planes, respectively, of the ray from the transmitter to the (first) reflection point. For the direct ray, these would be the angles to the receiver. They are used, after being converted to conical angles, to determine the angle in the antenna pattern that is pointed towards the specular point, or the receiver, to obtain the amplitude in that direction relative to the peak, in both azimuth and elevation.

d. TDEL - The time delay between the arrival of the direct signal and the multipath signal, in seconds. Time delay is used in conjunction with the phase to determine the multipath effect on the shape of the main beam.

e. TDOP - The total Doppler shift.

f. RDOP - The receiver Doppler. This is the receiver velocity in the direction of the multipath or direct ray. It is used to adjust the phase for the exact phase shift, taking into account the difference in the velocity vector towards the transmitter and the multipath reflection point.

g. AZIN and ELIN - The incident planar angles at the receiver of the direct or multipath signals. They are used to apply the aircraft antenna pattern effect to the signal amplitude. Currently, the model assumes an omnidirectional aircraft antenna pattern.

4.3.2 Unit PPID.

PPID is the logical unit associated with the file that transfers data between BMLST and BPLOTT. PPID contains information from BMLST that is to be plotted by the associated plotting program. The contents of this file are important to an understanding of BMLST and the results it produces for a given scenario.

The first two records of PPID contain the name and address of the organization performing the simulation and the date and time of execution of the propagation model. These parameters are initialized in the user written subroutine SINIT and are written to PPID by the program BMLST.

Following these identifying records is a complete copy of the formatted input file. This allows the user to verify the input data and provides the input data to BPLOTT.

The final record in the copy of the formatted input file consists of the words END DATA. Following this record are four integer flags indicating the transmitters that have been processed. The four integer flags can have values of either "0" (not requested) or "1" (requested) and represent, in order, azimuth, elevation, DME/P uplink, DME/P downlink. The flags are set by user responses in the interactive section of BMLST (see section 3.3.1).

The remainder of the PPID file contains the multipath information required by BPLOTT. The following information is written for each point on the flightpath (by subroutine DIGOUT):

a. STOP - A logical flag indicating whether or not this is the final flightpath point. It becomes true only when this is the case.

b. NEWSEG - A logical flag indicating whether or not the current flightpath point is the beginning of a new flightpath segment. If it is, the flag is set to TRUE; FALSE otherwise. The beginning of a new segment indicates the possibility of calculating a change in velocity and direction of the receiver aircraft. If the current point is within a segment, it is assumed to be have the same velocity and direction as the previous point.

c. XFP, YFP, ZFP - The X, Y, and Z coordinates of the current flightpath point.

d. DST - The distance along the flightpath, in feet, of the current flightpath point.

Following the above information, scattering and shadowing data are written for each transmitter requested for the current flightpath point. The scattering data are edited to include the highest multipath value for each scattering aircraft and building (a

maximum of 10 each), for the specular ground reflections (1 value), and for the diffuse ground reflections (1 value) for a total of 22 possible scattering obstacles. Scattering data written are:

a. DATAMP - The amplitude, in decibels, of the highest scattered ray for each scattering object (up to 22), for each transmitter (up to 4).

b. CONAN - The separation angle (conical angle in degrees) between the direct ray and the scattered ray corresponding to the amplitude stored in DATAMP. If the transmitter is the DME/P, this value will be a time delay in nanoseconds.

After the above scattering data are written for each scattering obstacle, one value is written summarizing the effect of shadowing on the amplitude of the direct signal at the current flightpath point.

a. SHDAMP - The amplitude (in decibels) of the direct signal at the current flightpath point. It includes the effects that have been calculated from all shadowing obstacles.

After the scattering and shadowing data for the entire flightpath are recorded in PPID, summary data are provided for later inclusion in the plot tables provided by BPLOTT. First, for each of the transmitters processed, the following data are written:

a. PEKAMP - The peak amplitudes (in decibels) of all multipath components (up to 22) for each transmitter (up to 4). These data are included on the multipath ranking lists provided by BPLOTT.

b. MMPIND - The index number of the flightpath point at which the PEKAMP value occurs. These data are included on the multipath ranking lists provided by BPLOTT.

c. RNKDOP - The Doppler at the flightpath point where the peak amplitude occurs. It is not currently used.

After summary values are written for each transmitter, the following data are written:

a. NFLTPT - An integer indicating the total number of points in the flightpath for which multipath data were determined.

b. DST - The total distance along the flightpath, in feet. It is the distance value associated with the final flightpath point.

c. DSTMIN - The minimum distance along the flightpath, in feet. It is the distance value associated with the initial flightpath point and should be 0.0.

The final section of summary data includes minimum and maximum values for scattering and shadowing data to allow correct scaling for the plots produced by BPLOTT. Data which are written for each transmitter are:

a. TRCMX - The X axis and Y axis values at which the maximum occurs for the scattering plots. The X axis value is in feet. The Y axis value may be decibels, degrees, or nanoseconds, as appropriate. Up to 22 X-Y pairs may be stored for each transmitter.

b. TRCMN - The X axis and Y axis values at which the minimum occurs for the scattering plots. The units are as above.

c. SHMAX - The maximum shadowing value (in decibels) for each transmitter.

d. SHMIN - The minimum shadowing value (in decibels) for each transmitter.

<u>4.3.3 Unit PRID</u>.

PRID is the logical unit associated with the file that transfers data between BMLSR and BPLOTR. PRID contains information from BMLSR that is to be plotted by the associated plotting program. The contents of this file are important to an understanding of BMLSR and the results it produces for a given scenario.

The first two records of PRID contain the name and address of the organization performing the system simulation and the date and time of execution of the system model. These parameters are initialized in the user written subroutine SINIT and are written to PRID by the program BMLSR. The next two records, read from PID and written to PRID by BMLSR, contain the name and address of the organization performing the propagation simulation and the date and time of execution of the propagation model.

Following these identifying records is a complete copy of the formatted input file. This allows the user to verify the input data and provides the input data to BPLOTR.

The final record in the copy of the formatted input file consists of the words END DATA. Following this record are six integer flags indicating the transmitters that have been processed, the status of the perturbation smoothing option, and the choice of receiver algorithm. The six integer flags can have values of either "0" (not requested) or "1" (requested) and represent, in order, azimuth, elevation, DME/P uplink, DME/P downlink, perturbation smoothing, and split gate receiver algorithm. (If split gate is not chosen, dwell gate processing is implemented.) The flags are set by user responses in the interactive section of BMLSR (see section 3.3.3).

Following these flags, data are written for each flightpath point. The specific values written are

a. .FALSE. - A logical value indicating that the current point is not the final flightpath point.

b. RCVR - The X, Y, and Z coordinates of the current flightpath point, in feet.

c. DIST - The distance in feet along the flightpath of the current flightpath point.

d. POINT - An integer indicating the index number of the current flightpath point. A negative value indicates that the point is a waypoint (as defined in the formatted input file).

e. DYERR - The dynamic error value (in degrees or feet), for each transmitter selected, for the current nominal flightpath point and the 12 perturbed points. This variable is initialized to +987.6543, and the value is written for any point that is not subsequently recalculated. If the flightpath point is out of coverage, the default value is changed to -999.99 for the angle systems. When a flag indicates problems with the point in the MLS receiver, the default value is changed to +999.99. The default value for a point flagged by the DME/P interrogator is +888.88. The default value is written to PRID unless an angle or range error is determined without problems. In that case, the error value is written to PRID.

f. STERR - The static error value (in degrees or feet), for each transmitter selected, for the current nominal flightpath point and the 12 perturbed points. This variable is initialized to +987.6543, and the value is written for any point that is not subsequently recalculated. If the flightpath point is out of coverage, the default value is changed to -999.99 for the angle systems. When a flag indicates problems with the current point in the MLS receiver, the default value is changed to +999.99. The default value for a point flagged by the DME/P interrogator is +888.88. The default value is written to PRID unless an angle or range error is determined without problems. In that case, the error value is written to PRID.

After all error data have been written to PRID, one final line of data is written consisting of:

a. .TRUE. - A logical value indicating the final flightpath point.

b. ANTBW - The antenna beam widths for the azimuth and elevation, respectively.

c. 0.0 - **DME/P antenna "beamwidth", which is meaningless at this time, is set to 0.0.**

d. DIST - The total distance along the flightpath, in feet (i.e., the distance between the first and the final flightpath points).

e. POINT - The total number of points in the flightpath (i.e., the index number associated with the final flightpath point).

5. MESSAGES.

The MLS mathematical model displays messages to provide information to the user or to warn the user of possible errors. Some of the informational messages and warnings are part of the interactive section of the model and were discussed in the execution guide for each program. The other messages are discussed here. Most of the messages give information or warnings but do not disrupt program execution. In some cases, warnings are followed by termination of the program. All messages are written to the standard output device (unit ISOU) as initialized in SINIT.

5.1 MESSAGES FOUND IN ALL MODEL PROGRAMS.

Each of the four programs must read input from the formatted input file. Therefore, messages providing information or warnings about the contents of the input file are found in all programs. Any message included in the user written subroutines SINIT and SOPEN will also be displayed by all programs.

5.1.1 Information Messages.

As each section of the input file is read, the message

"SECTION NUMBER (X) BEING PROCESSED"

is displayed (where X indicates the section number being read). This enables the user to verify that the desired sections are, in fact, present. Note that it is not necessary for all sections of the input file to be included in a particular scenario. Each program reads (and displays the above message for) only those sections of the input file that it requires for processing.

5.1.2 Warning Messages.

Three types of warnings can be displayed during the process of reading the formatted input file. The first case arises when there are too many data items listed in a section with an explicit limit. A warning is displayed, and only the maximum allowable number of data items are read. An example of the warning message, in this case for scattering aircraft, is:

**"THE NUMBER OF SCATTERING AIRCRAFT ENTERED WAS 13.
ONLY THE FIRST 10 WERE ACCEPTED."**

The options for which this message may be displayed, the sections in the formatted input file in which they are defined, and the maximum allowable number of data items for each option, are:

Section 3 - Scattering aircraft (10)
Section 4 - Scattering buildings (10)
Section 5 - Ground rectangles (10)
Section 6 - Ground triangles (10)
Section 8 - Shadowing aircraft (10)
Section 9 - Shadowing buildings (10)
Section 11 - Runway profile coordinates (20 sets)
Section 12 - Flightpath waypoints (36)

The second type of warning is displayed when there are no data present in a section for which processing has been requested and data are expected. In this event, the flag requesting processing is disabled, and processing is not performed. An example of this type of warning is:

**"SCATTERING AIRCRAFT WERE REQUESTED BUT NO DATA WERE ENTERED
ASSUMING NO SCATTERING AIRCRAFT."**

This type of warning may be displayed for:

Section 3 - Scattering aircraft
Section 4 - Scattering buildings
Section 5 - Ground rectangles
Section 6 - Ground triangles
Section 8 - Shadowing aircraft
Section 9 - Shadowing buildings
Section 10 - Runway hump coordinates
Section 11 - Runway profile coordinates
Section 12 - Flightpath waypoints

The third type of warning occurs when the program cannot interpret the answer to the question requesting processing of a section of the input file. If this occurs, the program will disable processing of that section and print a warning message to that effect. An example message is:

**"RESPONSE TO QUESTION REQUESTING SCATTERING AIRCRAFT
WAS IN ERROR --
ASSUMING NO SCATTERING AIRCRAFT."**

5.2 MESSAGES FOUND IN BMLST.

On occasion, an error occurs in the processing of BMLST that makes continuation of execution impossible or undesirable. In this event, a message is displayed, and the program is terminated. If an error occurs that does not require termination, the user is informed of the error and should interpret the output data accordingly. Other messages in BMLST are displayed so that the user can verify the desired processing options.

5.2.1 Termination Messages.

When BMLST terminates normally, a message is displayed informing the user of the time of termination. The time is determined by operating system calls in the user written subroutine SINIT. The message is:

"PROCESSING COMPLETED AT (TIME)"

If the file specified for input of a measured flightpath is empty, the following message is given, and the program is terminated since it cannot continue processing without a flightpath:

"EMPTY MEASURED FLIGHTPATH DATA FILE"

In the processing of specular ground reflections from tilted ground surfaces, BMLST permits the input of ten rectangles and ten triangles. If more than ten surfaces of each type are found in the input file, only the first ten are read in. If this trap fails to keep the number of specular ground elements within the required limit of 21 (20 tilted surfaces plus flat specular ground), the following message is displayed, and execution is terminated:

**"THE NUMBER OF SPECULAR GROUND ELEMENTS EXCEEDS 21.
STOP IN SUBROUTINE GRNDLD"**

Rectangular and triangular specular ground reflection elements are specified with three sets of coordinates for three corners. If these elements are found to have equal Y coordinates for points 1 and 2, BMLST displays an error message and terminates execution.

**"SPECULAR GROUND SURFACE NO. (X) WAS SPECIFIED INCORRECTLY.
STOP IN SUBROUTINE INIT"**

5.2.2 Warning and Information Messages.

The processing of specular ground rectangular and triangular surfaces requires that three points be entered in the input file in ascending order of the X coordinates. If the points are not specified in this order, they are reordered, and the following message is displayed:

"SPECULAR GROUND SURFACE NO. (X) WAS SPECIFIED INCORRECTLY. REORDERING WAS PERFORMED."

The imaginary part of the complex dielectric constant of each specular ground surface is checked to be sure it is negative. If it is not, it is converted to a negative value (i.e., the magnitude of the imaginary component is negated), and the following message is displayed:

"COMPLEX DIELECTRIC CONSTANT FOR GROUND SURFACE (X) WAS SPECIFIED INCORRECTLY.
POSITIVE IMAGINARY COMPONENT CONVERTED TO NEGATIVE."

For information, BMLST displays a message whenever the main subroutine of an execution option is called. This enables the user to verify that the desired execution options are being implemented. An example of this type of message is:

"BUILDING REFLECTION (BREFC) SUBROUTINE CALLED"

A similar message is displayed by the associated subroutine for each of the following execution options:

Scattering buildings (subroutine BREFC)
Scattering aircraft fuselage (subroutine FREFC)
Scattering aircraft tail fin (subroutine TREFC)
Specular ground reflections (subroutine GREFC)
Shadowing aircraft and buildings (subroutine SHDARB)
Runway hump shadowing (subroutine SHDHMP)

5.3 MESSAGES FOUND IN BPLOTT.

There are no termination messages in BPLOTT. In addition to the read subroutine messages and warnings, only one other warning message appears. However, there may be additional messages or termination conditions in the user written graphics interface subroutines.

The arrays that hold the data for plotting by BPLOTT are dimensioned to contain 3000 data points. If more than 3000 points are read, the following message appears:

"NUMBER OF DATA POINTS FOR PLOTTING EXCEEDS 3000.
-- ONLY FIRST 3000 ACCEPTED"

5.4 MESSAGES FOUND IN BMLSR.

There are no warning or informational messages in BMLSR other than those found in all programs. If the confidence counter and flag information option is selected, warning messages concerning flags and dwell gate crossings are written to logical unit RDO.

5.4.1 Termination Messages.

When BMLSR terminates normally, a message is displayed informing the user of the time of termination. The time is determined by operating system calls in the user written subroutine SINIT. The message is:

"PROCESSING COMPLETED AT (TIME)"

The processing in BMLSR is directly involved with the pattern of the transmitting antenna(s) specified in the input file. If this specification is invalid, processing cannot continue. Therefore, a message indicating the invalid antenna type is displayed, and execution is halted. Note that the antenna type is evaluated with a string matching procedure. Therefore, the type must be specified with the first letter in the first column of the template area. Leading blanks in the antenna type specification are the most common cause of this error. An example of the error message is:

"AZNB IS AN INVALID ANTENNA TYPE.
CHECK FOR LEADING BLANKS IN SPECIFICATION OF ANTENNA TYPE.
STOP IN SUBROUTINE READ1A FOR AZIMUTH ANTENNA TYPE."

Similar messages are displayed for invalid specification of elevation or DME/P antenna types.

A message is also displayed, and execution is terminated, if an invalid pulse shape is entered for either DME/P uplink or DME/P downlink. The message is:

"INVALID PULSE SHAPE FOR DME/P UPLINK (OR DOWNLINK)
STOP IN SUBROUTINE DINIT"

The arrays in BMLSR are dimensioned to allow only 20 multipath components which is the limit written by BMLST after editing. In the unlikely event that more than 20 components are read, BMLSR will stop execution with the following messages:

"NUMBER OF MULTIPATH COMPONENTS IS GREATER THAN 20.
NUMBER OF COMPONENTS: (X)
FLIGHTPATH POINT NUMBER: (X)
DISTANCE ALONG FLIGHTPATH: (X)
TRANSMITTING ANTENNA: AZIMUTH
STOP IN SUBROUTINE RDMULT"

Although it is unlikely that the simulation of an MLS receiver will fail, this can happen, in which case the following messages will be displayed and the program will terminate:

"FAILED SEARCH FOR TO ENVELOPE THRESHOLD
LEADING INDEX: (X)
TRAILING INDEX: (X)

ENVELOPE ARRAY: (10 VALUES PRINTED)
STOP IN SUBROUTINE TRSB"

Similar messages are printed in the event of a failed search for the FRO envelope threshold. Another error that will cause BMLSR to terminate is a failed initial acquisition. The message printed is:

"FAILED DWELL GATE/THRESHOLD SEARCH FOR INITIAL ACQUISITION
POSSIBLE BEAMWIDTH PROBLEM WITH AZIMUTH (OR ELEVATION)
STOP IN SUBROUTINE TRSB"

5.5 MESSAGES FOUND IN BPLOTR.

In addition to the read messages and warnings, BPLOTR displays termination and warning messages which are discussed below. There may be additional messages or termination conditions in the user written graphics interface subroutines.

5.5.1 Termination Messages.

BPLOTR will terminate if an invalid antenna type is entered for azimuth, elevation, or DME/P. The messages displayed are the same as those for BMLSR. An example is:

"AZNB IS AN INVALID ANTENNA TYPE.
CHECK FOR LEADING BLANKS IN SPECIFICATION OF ANTENNA TYPE.
STOP IN SUBROUTINE READ1A FOR AZIMUTH ANTENNA TYPE."

5.5.2 Warning and Information Messages.

The arrays that hold the data for plotting by BPLOTR are dimensioned to contain 3000 data points. If more than 3000 points are read, the following message appears:

"NUMBER OF DATA POINTS FOR PLOTTING EXCEEDS 3000.
-- ONLY FIRST 3000 ACCEPTED"

ABBREVIATIONS AND ACRONYMS

ANG	Angle
ANSI	American National Standards Institute
ARDH	Approach Reference Datum Height
AZ	Azimuth
BMLSR	Baselined MLS Receiver (System) program
BMLST	Baselined MLS Transmitter (Propagation) program
bpi	Bits per inch
BPLOTR	Baselined Plot program for Receiver program output data
BPLOTT	Baselined Plot program for Transmitter program output data
CMN	Control Motion Noise
DAC	Delay Attenuate Compare (to determine DME threshold)
dB	Decibels
DME/P	Distance Measuring Equipment/Precision
EL	Elevation
FA	Final Approach
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FREQ	Frequency
Hz	Hertz
ICAO	International Civil Aviation Organization
IF	Intermediate Frequency
ILS	Instrument Landing System
INC	Increment
LOS	Line of Sight
LSL	Lower Scan Limit
M/D	Multipath/Direct
MGPA	Minimum Glidepath Angle
MHz	Megahertz
MIT	Massachusetts Institute of Technology
MLS	Microwave Landing System
NATO	North Atlantic Treaty Organization
NIAG	Nato Industrial Advisory Group
nmi	Nautical Miles
PAF	Peak Amplitude Find (to determine DME threshold)
PC	Personal Computer
PFE	Path Following Error (bias component of error)
PID	Propagation Model Input Device (variable name for the logical unit number for the formatted input file, input to BMLST)
PPID	Plotting Propagation Input Device (variable name for the logical unit number for the data file which is output from BMLST and input to BPLOTT)
PPOD	Plotting Propagation Output Device (variable name for the logical unit number for the data file or device to which output by BPLOTT is directed)
PRID	Plotting Receiver Input Device (variable name for the logical unit number for the data file which is output from BMLSR and input to BPLOTR)

PROD	Plotting Receiver Output Device (variable name for the logical unit number for the data file or device to which output by BPLOTR is directed)
RF	Radio Frequency
RID	Receiver Input Device (variable name for the logical unit number for the data file which is output from BMLST and input to BMLSR)
RDO	Receiver Diagnostic Output (variable name for the logical unit number for the data file which is output by BMLSR containing flag and counter information)
rms	Root mean square
SF	Surface Flag
SINIT	Site Initialization subroutine (linked with BMLST, BMLSR, BPLOTT, and BPLOTR)
SOPEN	Site Open subroutine (linked with BMLST, BMLSR, BPLOTT, and BPLOTR)
TIM	Time
TRSB	Time-Reference Scanning Beam
USL	Upper Scan Limit
VEL	Velocity

BIBLIOGRAPHY

Capon, J., Multipath Parameter Computations for the MLS Simulation Computer Program, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-68 (FAA-RD-76-55), April 8, 1976.

Evans, J. E., Burchsted, R., Capon, J., Orr, R. S., Shnidman, D. A., and Sussman, S. M., MLS Multipath Studies, Volume I: Mathematical Models and Validation, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-63 (FAA-RD-76-3), February 25, 1976.

Evans, J. E., Burchsted, R., Capon, J., Orr, R. S., Shnidman, D. A., and Sussman, S. M., MLS Multipath Studies, Volume II: Application of Multipath Model to Key MLS Performance Issues, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-63 (FAA-RD-76-3), February 25, 1976.

Evans, J. E., Sun, J. F., Dolinar, S. J., and Shnidman, D. A., MLS Multipath Studies, Phase 3 Final Report, Volume I: Overview and Propagation Model Validation/Refinement Studies, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-88 (FAA-RD-79-21), April 25, 1979.

Evans, J. E., Dolinar, S. J., Shnidman, D. A., and Burchsted, R. C., MLS Multipath Studies, Phase 3 Final Report, Volume II: Development and Validation of Model for MLS Techniques, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-88, (FAA-RD-79-21), February 7, 1980.

Evans, J. E., Dolinar, S. J., and Shnidman, D. A., MLS Multipath Studies, Phase 3 Final Report, Volume III: Application of Models to MLS Assessment Issues (two parts), Lincoln Laboratory, Massachusetts Institute of Technology, ATC-88 (FAA-RD-79-21), June 8, 1981.

Evans, J. E. and Swett, P. H., Results of L Band Multipath Measurements at Operational United States (U.S.) Airports in Support of the Microwave Landing System (MLS) Precision Distance Measuring Equipment (DME/P), Lincoln Laboratory, Massachusetts Institute of Technology, ATC-109 (DOT/FAA/RD-81/63), July 23, 1981.

Introduction to MLS, Department of Transportation, Federal Aviation Administration, Program Engineering and Maintenance Service, Washington, D.C., October 1987.

Jones, J. D., The Addition of Bendix MLS Antenna Patterns to the MLS Mathematical Model, Department of Transportation, Federal Aviation Administration Technical Center, DOT/FAA/CT-TN89/26, May 1989.

Jones, J. D., Microwave Landing System (MLS) Mathematical Model Installation Manual, Department of Transportation, Federal Aviation Administration Technical Center, DOT/FAA/CT-TN87/17, May 1987.

Jones, J. D., Program Validation of Lincoln Laboratory Microwave Landing System Math Model, Department of Transportation, Federal Aviation Administration Technical Center, DOT/FAA/CT-TN84/42, November 1984.

Kelly, R. J. and Cusick, D. R., "Distance Measuring Equipment and Its Evolving Role in Aviation," Bendix Communications Division, Towson, Maryland, 1985, published in Advances in Electronics and Electron Physics, Vol. 68.

MLS Microwave Landing System Indoctrination Handbook, Department of Transportation, Federal Aviation Administration, Program Engineering and Maintenance Service, Washington, D.C., September 1985.

Pasquale, L. and Jones, J. D., Approach to Validation of the MLS Mathematical Model, Department of Transportation, Federal Aviation Administration Technical Center, ACD-330-90-04.

Redlien, H. W. and Kelly, R. J., "MLS Microwave Landing System: The New International Standard," Bendix Communications Division, Baltimore, Maryland, 1981, published in Advances in Electronics and Electron Physics, Vol. 57.

Shnidman, D. A., The Logan MLS Multipath Experiment, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-55 (FAA-RD-75-130), September 23, 1975.

Shnidman, D. A., Airport Survey for MLS Multipath Issues, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-58 (FAA-RD-75-195), December 15, 1975.

Sun, D. F., Experimental Measurements of Low Angle Ground Reflection Characteristics at L- and C-Bands for Irregular Terrain, Lincoln Laboratory, Massachusetts Institute of Technology, ATC-107 (DOT/FAA/RD-81/65), November 1, 1982.

APPENDIX

TABULAR AND GRAPHIC INPUT AND OUTPUT

LIST OF TABLES

TABLE A-1. SAMPLE INPUT FILE

```
********************MLS MATHEMATICAL MODEL INPUT DATA FILE************************
SECTION  0
           = SCENARIO DATA
           RUN ID# :1281
           TITLE   :LAX WITHOUT SNOW
           AIRPORT :LAX
           RUNWAY  :24R
           LENGTH  :8700.
           WIDTH   :150.
           ARDH    :50.
           MGPA    :3.0
           UNITS   :FEET  (feet, meter) FOR ENTRIES IN FILE
SECTION 1A
           = ANGLE TRANSMITTER DATA
           PHASE CENTER:  X         Y          Z     FREQ(mhz)  LSL   USL    TYPE
                      -------- -------- -------- --------- ----- ----- --------
           AZIMUTH  :  -1000.0       0.0       5.0  4992.291 -60.0 60.0  AZBN
           ELEVATION:   7900.0    -400.0      13.0  4992.291   0.9 20.0  ELBN
SECTION 1D
           = DME/P TRANSMITTER DATA
           PHASE CENTER:  X         Y          Z      TYPE
                      -------- -------- -------- --------
           DME/P    : -1000.0  0.0       5.0       DMBN

           = OTHER DME DATA
                      FREQ(mhz)   SHAPE    TRG  F    SW    AS    TRS  SIGM   RMI
                      --------- --------- --- --- ----- ----- ----- ----- -----
           UPLINK   : 983.4813  GC2C22000 PAF NOF .5    .5    .125  0.0   0.0
           DOWNLINK : 983.4813  GC2C22000 PAF NOF .5    .5    .125  0.0   0.0
SECTION  2
           YES - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
           YES  - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
           = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
           DIELECTRIC CONSTANT : 1.2        0.0
           ROUGHNESS HEIGHT    : 0.0
          * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
           DIELECTRIC CONSTANT : 1.2        0.0
           ROUGHNESS HEIGHT    : 0.0
SECTION  3
           = SCATTERING FROM AIRCRAFT (MAXIMUM OF 10)
           YES - RUN AIRCRAFT SCATTERING (yes,no)
        ## X-TAIL   Y-TAIL   X-CKPT   Y-CKPT     ALT    AT  GRCORR
        -- -------- -------- -------- -------- -------- -- --------
        nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy aaaaaaaa tt cccccccc
        01 5700.0   -1150.0  5900.0   -1150.0  0.0       1 0.0
        02 6700.0   -1150.0  6900.0   -1150.0  0.0       1 0.0
        03 8758.6   -1150.0  8900.0   -1008.6  0.0       1 0.0
        04 8900.0    -900.0  8900.0    -700.0  0.0       1 0.0
SECTION  4
           = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
           YES - RUN SCATTERING BUILDINGS (yes,no)
        ## X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT    GRCORR   CMP
        -- -------- -------- -------- -------- ----- ----- ----- -------- -----
        nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
        01 3975.0   -3400.0  4400.0   -3400.0  0.0   100.0 0.0   0.0      METAL
        02 4550.0   -2100.0  5080.0   -2100.0  0.0   100.0 0.0   0.0      METAL
        03 4800.0   -3100.0  5200.0   -3100.0  0.0   100.0 0.0   0.0      METAL
        04 6825.0   -1800.0  7125.0   -1800.0  0.0    50.0 0.0   0.0      METAL
        05 7780.0   -1800.0  8080.0   -1800.0  0.0    50.0 0.0   0.0      METAL
        06 7125.0   -1800.0  7252.0   -1706.0  0.0    50.0 0.0   0.0      METAL
        07 8080.0   -1800.0  8209.0   -1706.0  0.0    50.0 0.0   0.0      METAL
```

TABLE A-1. SAMPLE INPUT FILE (CONTINUED)

```
SECTION  5
         = SPECULAR SCATTERING FROM RECTANGULAR GROUND SURFACES (MAX OF 10)
         YES - RUN RECTANGULAR GROUND (yes,no)
         THIS DATA MAY BE SKIPPED
      ##  X-VALU   Y-VALU   Z-VALU   DCREAL   DCIMAG   ROUGHN   SF
      -- -------- -------- -------- -------- -------- -------- --
      nn x1x1x1x1 y1y1y1y1 z1z1z1z1 rrrrrrrr iiiiiiii rrrrrrrr is
         x2x2x2x2 y2y2y2y2 z2z2z2z2
         x3x3x3x3 y3y3y3y3 z3z3z3z3
      01 0.0      -75.0    0.0      5.0      0.0      .006562  0
         0.0      75.0     0.0
         8700.0   75.0     0.0
SECTION 10
         = SHADOWING BY RUNWAY HUMP
         YES - RUN SHADOWING HUMP (yes,no)
          X-FRONT  Z-FRONT  X-HUMP   Z-HUMP   X-BACK   Z-BACK
         -------- -------- -------- -------- -------- --------
         xfxfxfxf zfzfzfzf xhxhxhxh zhzhzhzh xbxbxbxb zbzbzbzb
         3300.0   0.0      3800.0   5.0      4300.0   0.0
SECTION 12
         = FLIGHTPATH
         FAF      : 6.2      NAUTICAL MILES
         DATUM    : 7900.0   0.0      0.0
         TYPE     : SEGMENTED   (measured, distance, orbit, radial,
       *                         segmented, straight)
         VELOCITY : 219.56
         INCREMENT: 43.91
         DATA RATE:  0.20
       *  IF "straight" SUFFICIENT DATA IS AVAILABLE TO COMPUTE FLIGHTPATH
       *  IF "radial" ENTER ANGLE, ELEVATION, STARTING and ENDING DISTANCE
       * (nm from dme/p)
         ANGLE: aaaaaaaa
         SDIST: dddddddd
         EDIST: dddddddd
         ELEV : eeeeeeee
       *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
         RADIUS: rrrrrrrr
         ELEV  : eeeeeeee
       *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
       *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
       *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
       *      INCREMENT
      ##    XS       YS       ZS       VEL      INC
      -- -------- -------- -------- -------- --------
      nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
      01  17700.0      0.0    500.0   219.56    43.91
      02   7700.0      0.0      0.0      0.0      0.0
SECTION 13
         = FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS
       * FLIGHTPATH PLOTS:
                               X/Y PLOT     X/Z PLOT      D/Z PLOT
                              ----------   ----------    ----------
           MINIMUM X VALUE :  -3000.00 ft  -3000.00 ft     -0.25 nm
           UNITS PER INCH  :   3000.00 ft   3000.00 ft      0.25 nm
           MINIMUM Y VALUE :  -3000.00 ft   -100.00 ft   -100.00 ft
           UNITS PER INCH  :   1000.00 ft    100.00 ft    100.00 ft
       * AIRPORT LAYOUT PLOT:
                               X/Y PLOT
                              ----------
           MINIMUM X VALUE :  -2000.00 ft
           UNITS PER INCH  :   2000.00 ft
           MINIMUM Y VALUE :  -4000.00 ft
           UNITS PER INCH  :   1000.00 ft
```

TABLE A-1. SAMPLE INPUT FILE (CONTINUED)

```
SECTION 14
         = ANGLE EQUIPMENT AXIS LIMITS
         * MULTIPATH DIAGNOSTIC PLOTS:
                                    M/D        SEP ANG     SHADOWING
                                 ---------   ---------   ---------
             MINIMUM X VALUE :    -0.50 nm    -0.50 nm    -0.50 nm
             UNITS PER INCH  :     0.25 nm     0.25 nm     0.25 nm
             MINIMUM Y VALUE :   -40.00 db   -40.00 deg  -10.00 db
             UNITS PER INCH  :    10.00 db    10.00 deg    2.00 db
         * RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:
                                    RAW          PFE         CMN
                                 ---------   ---------   ---------
             MINIMUM X VALUE :    -0.50 nm    -0.50 nm    -0.50 nm
             UNITS PER INCH  :     0.25 nm     0.25 nm     0.25 nm
             MINIMUM Y VALUE :    -0.30 deg   -0.30 deg   -0.30 deg
             UNITS PER INCH  :     0.10 deg    0.10 deg    0.10 deg
SECTION 15
         = DISTANCE MEASURING EQUIPMENT AXIS LIMITS
         * MULTIPATH DIAGNOSTIC PLOTS:
                                    M/D       TIM DELAY   SHADOWING
                                 --------    ---------   ---------
             MINIMUM X VALUE :   -0.50 nm     -0.50 nm    -0.50 nm
             UNITS PER INCH  :    0.25 nm      0.25 nm     0.25 nm
             MINIMUM Y VALUE :  -40.00 db      0.00 ns   -10.00 db
             UNITS PER INCH  :   10.00 db    500.00 ns     2.00 db
         * RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:
                                    RAW          PFE         CMN
                                 ---------   ---------   ---------
             MINIMUM X VALUE :    -0.50 nm    -0.50 nm    -0.50 nm
             UNITS PER INCH  :     0.25 nm     0.25 nm     0.25 nm
             MINIMUM Y VALUE :  -270.00 ft  -180.00 ft  -180.00 ft
             UNITS PER INCH  :    90.00 ft    60.00 ft    60.00 ft
END DATA
```

TABLE A-2. RUN PARAMETERS FOR AIRPORT, TRANSMITTERS, AND EDITING

PROGRAM TO DO MULTIPATH MODELING AND SIMULATION OF MLS

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

AIRPORT PARAMETERS:

RUN TITLE : LAX WITHOUT SNOW

AIRPORT : LAX
RUNWAY : 24R
RUNWAY LENGTH : 8700.00 FEET
RUNWAY WIDTH : 150.00 FEET
APPROACH REFERENCE DATUM HEIGHT : 50.00 FEET
MINIMUM GLIDE PATH ANGLE : 3.00 DEG

PARAMETERS FOR AZIMUTH SYSTEM:

PARAMETER	VALUE	UNITS
AZIMUTH X	-1000.00	FEET
AZIMUTH Y	0.00	FEET
AZIMUTH Z	5.00	FEET
AZ FREQUENCY	4992.29	MHZ

PARAMETERS FOR ELEVATION SYSTEM:

PARAMETER	VALUE	UNITS
ELEVATION X	7900.00	FEET
ELEVATION Y	-400.00	FEET
ELEVATION Z	13.00	FEET
EL FREQUENCY	4992.29	MHZ

PARAMETERS FOR DME/P SYSTEM:

PARAMETER	VALUE	UNITS
DME/P X	-1000.00	FEET
DME/P Y	0.00	FEET
DME/P Z	5.00	FEET
DME/P UPLINK	983.48	MHZ
DME/P DOWNLINK	983.48	MHZ

MULTIPATH EDITING PARAMETERS:

OUT OF BEAMNESS:

AZIMUTH = 3.00 DEG
ELEVATION = 3.00 DEG
DME/P = 0.50E-05 SEC

TABLE A-3. RUN PARAMETERS FOR OBSTACLES

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

PARAMETERS USED IN COMPUTATION OF SPECULAR GROUND REFLECTION

DIELECTRIC CONSTANT (REAL,IMAG) = 1.2000 0.0000
ROUGHNESS = 0.0000
FULL FRESNEL-KIRCHOFF INTEGRATION FOR GROUND REFLECTION

RECTANGULAR SURFACE ELEMENTS ARE:

ID	X1 X2 X3	Y1 Y2 Y3	Z1 Z2 Z3	DCREAL	DCIMAG	ROUGHN
1	0.00	-75.00	0.00	5.0000	0.0000E+00	0.0066
	0.00	75.00	0.00			
	8700.00	75.00	0.00			

SURFACE FLAG(S) = 0

PARAMETERS USED IN COMPUTATION OF MULTIPATH REFLECTIONS

DIELECTRIC CONSTANT (REAL,IMAG) = 1.2000 0.0000
ROUGHNESS = 0.0000

BUILDING PARAMETERS ARE:

ID	X-LEFT	Y-LEFT	X-RIGHT	Y-RIGHT	ELV	HGT	TILT	GRCORR
1	3975.0	-3400.0	4400.0	-3400.0	0.0	100.0	0.0	0.00
2	4550.0	-2100.0	5080.0	-2100.0	0.0	100.0	0.0	0.00
3	4800.0	-3100.0	5200.0	-3100.0	0.0	100.0	0.0	0.00
4	6825.0	-1800.0	7125.0	-1800.0	0.0	50.0	0.0	0.00
5	7780.0	-1800.0	8080.0	-1800.0	0.0	50.0	0.0	0.00
6	7125.0	-1800.0	7252.0	-1706.0	0.0	50.0	0.0	0.00
7	8080.0	-1800.0	8209.0	-1706.0	0.0	50.0	0.0	0.00

ID	COMP	DCREAL	DCIMAG	ROUGHN
1	METAL	1.0000	-0.1000E+09	0.0000
2	METAL	1.0000	-0.1000E+09	0.0000
3	METAL	1.0000	-0.1000E+09	0.0000
4	METAL	1.0000	-0.1000E+09	0.0000
5	METAL	1.0000	-0.1000E+09	0.0000
6	METAL	1.0000	-0.1000E+09	0.0000
7	METAL	1.0000	-0.1000E+09	0.0000

AIRCRAFT PARAMETERS ARE:

ID	X-TAIL	Y-TAIL	X-CKPT	Y-CKPT	ALT	GRCORR	AT	TYPE
1	5700.00	-1150.00	5900.00	-1150.00	0.00	0.00	1	747
2	6700.00	-1150.00	6900.00	-1150.00	0.00	0.00	1	747
3	8758.60	-1150.00	8900.00	-1008.60	0.00	0.00	1	747
4	8900.00	-900.00	8900.00	-700.00	0.00	0.00	1	747

PARAMETERS USED IN COMPUTATION OF SHADOWING

RUNWAY HUMP SHADOWING PARAMETERS ARE:

	X	Y	Z
FRONT	3300.00	0.00	0.00
MIDDLE	3800.00	0.00	5.00
BACK	4300.00	0.00	0.00

TABLE A-4. FLIGHTPATH DATA

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

DATUM COORDINATES:

X: 7900.00 Y: 0.00 Z: 0.00

FLIGHTPATH TYPE: SEGMENTED

TABLE OF FLIGHTPATH AND WAYPOINT DATA

WAYPT ID	X-COORD (FT)	Y-COORD (FT)	Z-COORD (FT)	VELOCITY (FT/SEC)	SAMPLING INCR (FT)	DISTANCE (NM) ALONG FP
1	17700.00	0.00	500.00	219.56	43.91	0.00
2	7700.00	0.00	0.00	0.00	0.00	1.65

TABLE A-5. AZIMUTH MULTIPATH AMPLITUDE RANKINGS

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

AIRCRAFT & BUILDING MULTIPATH AMPLITUDE RANKINGS

******* AZIMUTH SYSTEM *******

OBST ID		RANK	MLTPATH AMP(DB)	X-AXIS REF
GRND	0	1	3.73	1.201
BLDG	1	4	-0.38	0.168
BLDG	2	2	1.59	0.363
BLDG	3	3	1.58	0.327
BLDG	4	9	-23.10	1.013
BLDG	5	10	-24.73	1.346
BLDG	6	11	-40.92	-0.172
BLDG	7	5	-2.01	-0.049
ACFT	1	8	-19.83	0.674
ACFT	2	7	-19.41	0.016
ACFT	3	6	-15.14	0.016
ACFT	4	12	-80.00	-0.027

TABLE A-6. ELEVATION MULTIPATH AMPLITUDE RANKINGS

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

AIRCRAFT & BUILDING MULTIPATH AMPLITUDE RANKINGS

******* ELEVATION SYSTEM *******

OBST ID		RANK	MLTPATH AMP(DB)	X-AXIS REF
GRND	0	1	2.18	-0.085
BLDG	1	5	-60.00	0.406
BLDG	2	6	-60.00	0.435
BLDG	3	7	-60.00	0.406
BLDG	4	8	-60.00	0.067
BLDG	5	2	-15.44	-0.078
BLDG	6	4	-53.98	0.038
BLDG	7	9	-60.00	0.002
ACFT	1	10	-60.00	1.461
ACFT	2	11	-60.00	1.440
ACFT	3	3	-26.20	-0.020
ACFT	4	12	-80.00	0.002

TABLE A-7. DME/P UPLINK MULTIPATH AMPLITUDE RANKINGS

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

AIRCRAFT & BUILDING MULTIPATH AMPLITUDE RANKINGS

******* DME/P UPLINK *******

OBST ID		RANK	MLTPATH AMP(DB)	X-AXIS REF
GRND	0	12	-80.00	1.483
BLDG	1	1	2.70	0.153
BLDG	2	2	0.98	0.269
BLDG	3	4	-2.35	0.406
BLDG	4	6	-22.16	1.028
BLDG	5	7	-23.35	1.353
BLDG	6	10	-35.39	-0.100
BLDG	7	3	0.21	-0.056
ACFT	1	9	-26.38	0.666
ACFT	2	8	-24.15	-0.020
ACFT	3	5	-16.71	-0.006
ACFT	4	11	-60.00	-0.035

TABLE A-8. DME/P DOWNLINK MULTIPATH AMPLITUDE RANKINGS

RUN ID: 1281 RUN DATE: 26-FEB-91 RUN TIME: 11:38:50

AIRCRAFT & BUILDING MULTIPATH AMPLITUDE RANKINGS

******* DME/P DOWNLINK *******

OBST ID		RANK	MLTPATH AMP(DB)	X-AXIS REF
GRND	0	12	-80.00	1.483
BLDG	1	1	2.70	0.153
BLDG	2	2	0.98	0.269
BLDG	3	4	-2.35	0.406
BLDG	4	6	-22.16	1.028
BLDG	5	7	-23.35	1.353
BLDG	6	10	-35.39	-0.100
BLDG	7	3	0.21	-0.056
ACFT	1	9	-26.38	0.666
ACFT	2	8	-24.15	-0.020
ACFT	3	5	-16.71	-0.006
ACFT	4	11	-60.00	-0.035

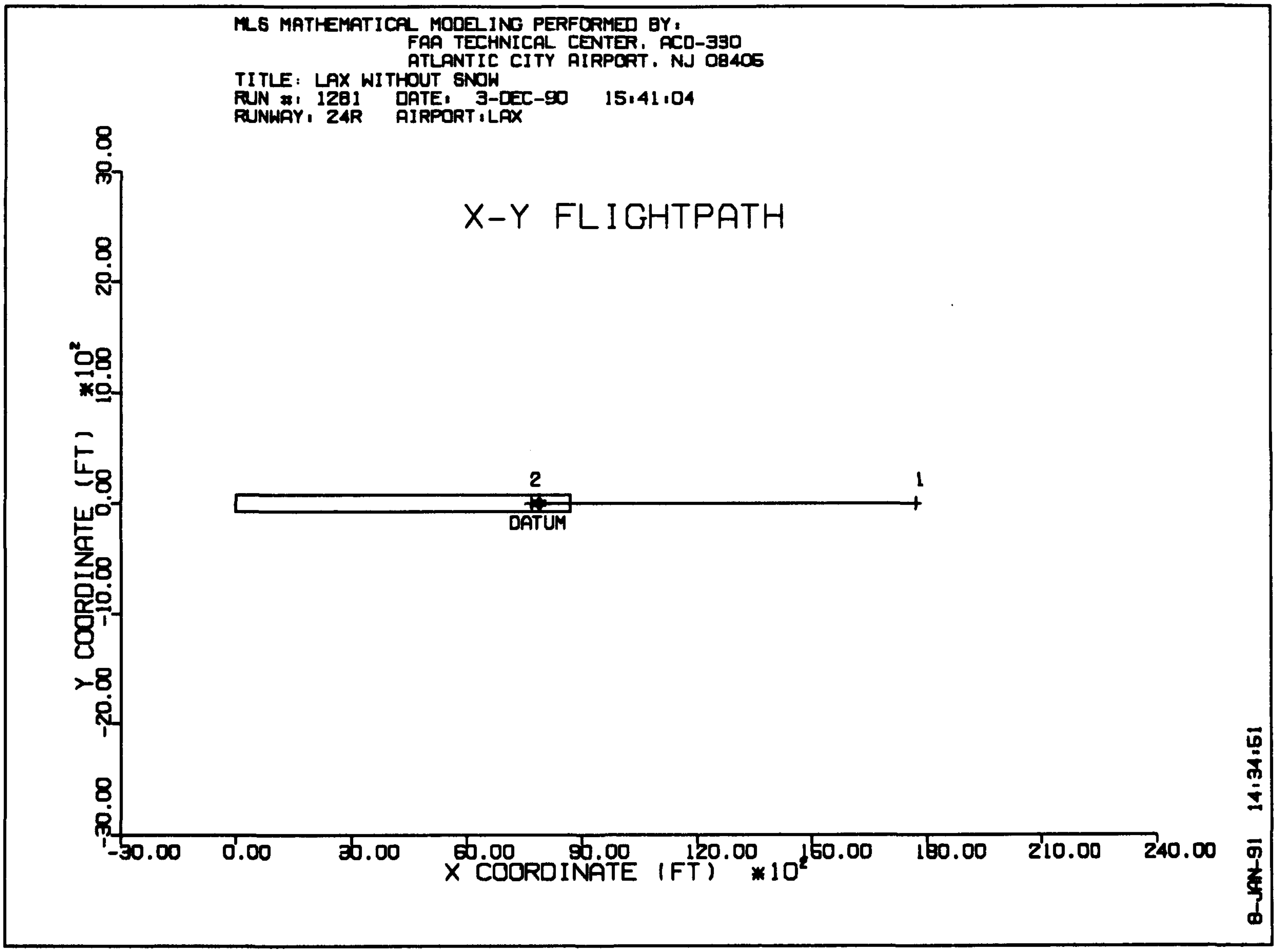

FIGURE A-1. FLIGHTPATH IN X - Y COORDINATE PLANE

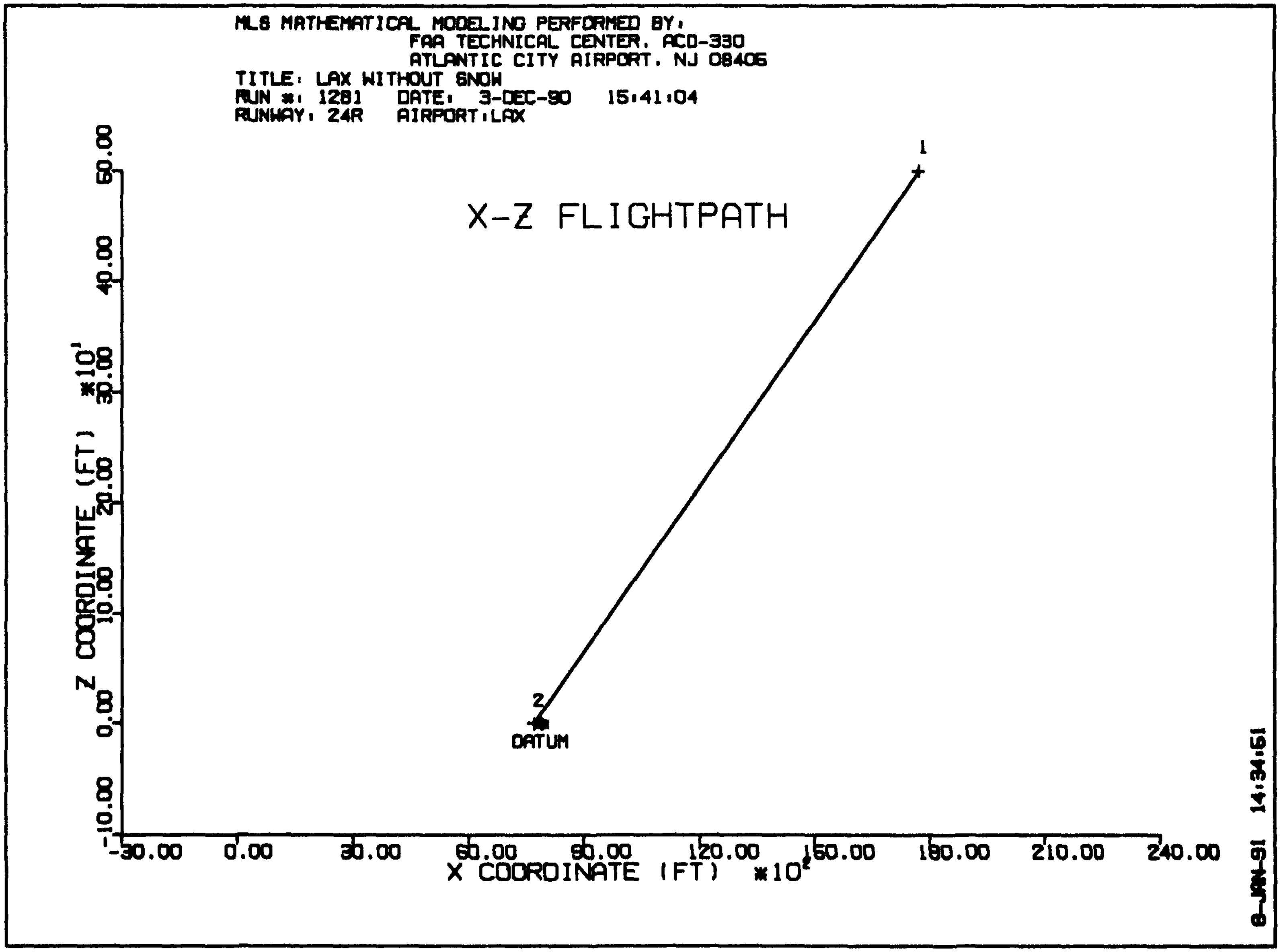

FIGURE A-2. FLIGHTPATH IN X - Z COORDINATE PLANE

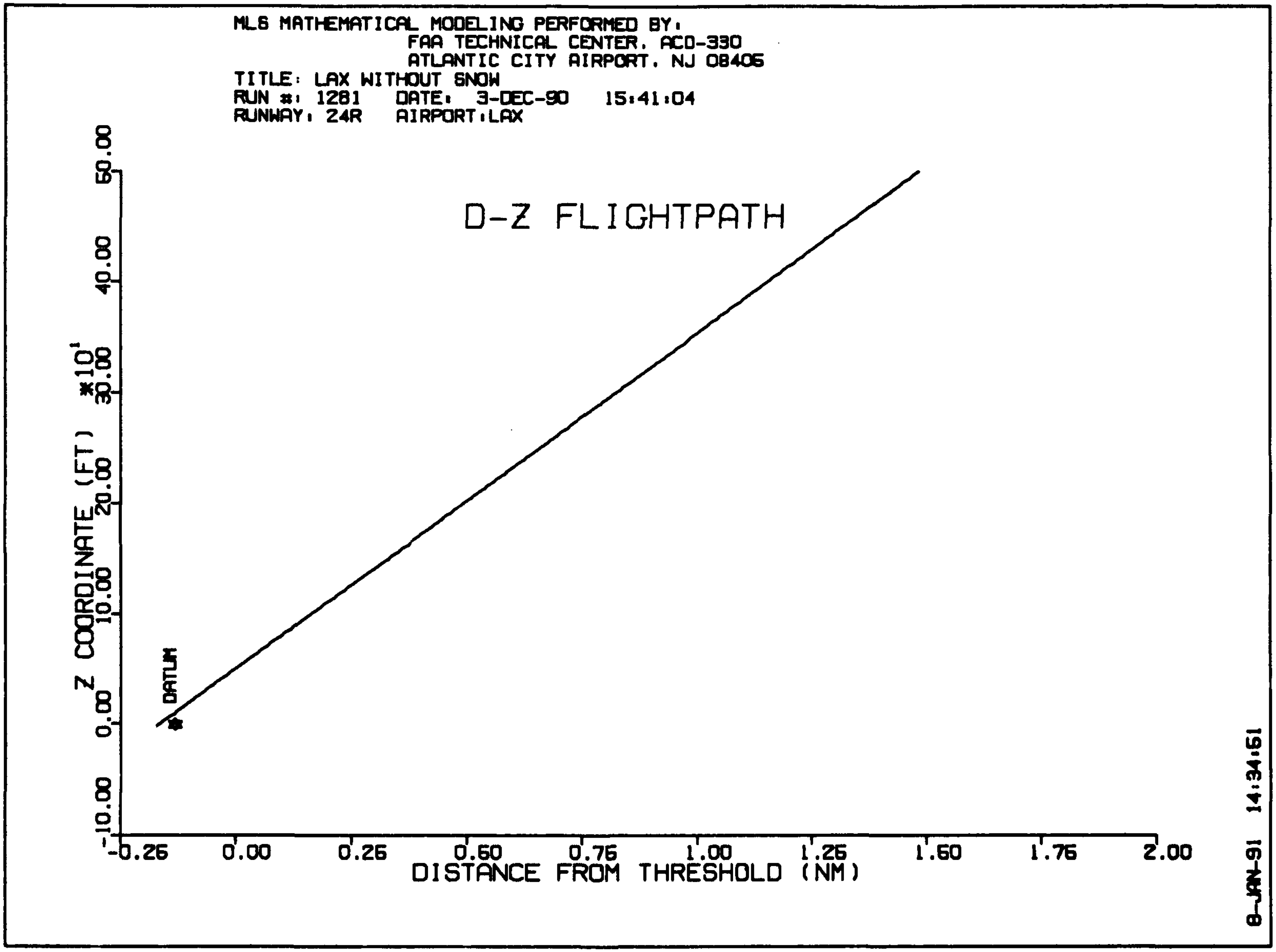

FIGURE A-3. FLIGHTPATH IN D - Z COORDINATE PLANE

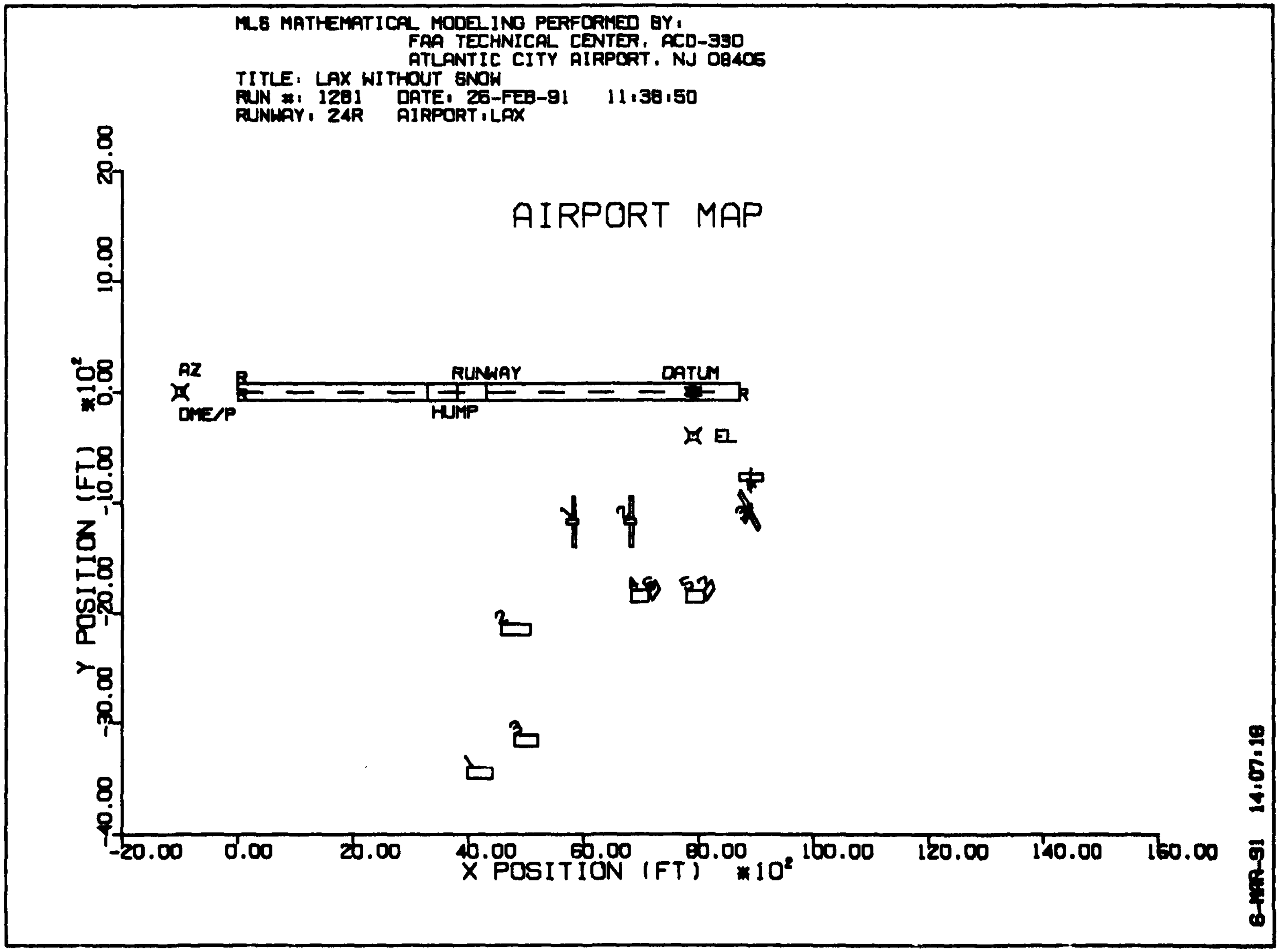

FIGURE A-4. AIRPORT MAP

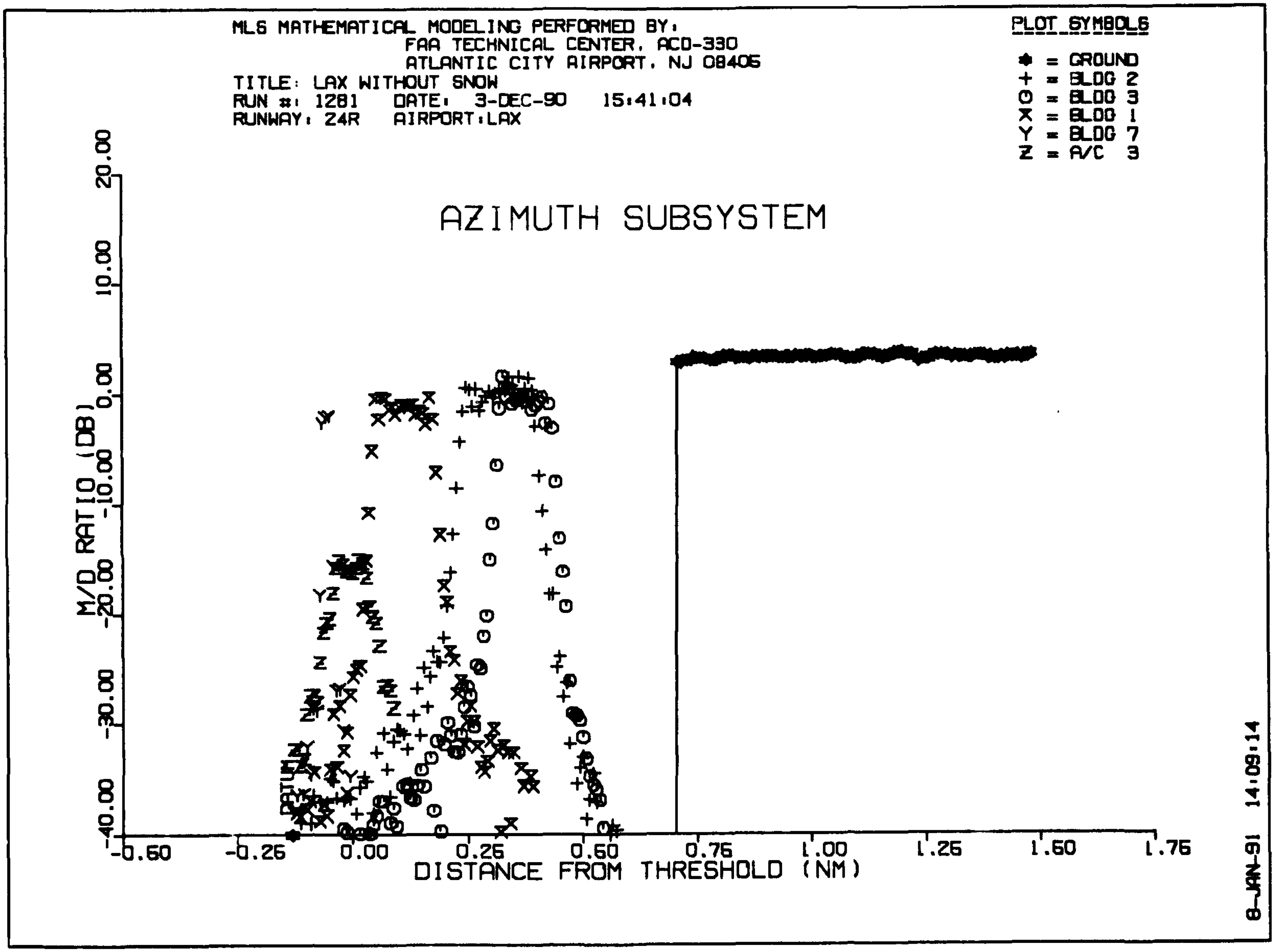

FIGURE A-5. AZIMUTH SUBSYSTEM - MULTIPATH/DIRECT SIGNAL RATIOS

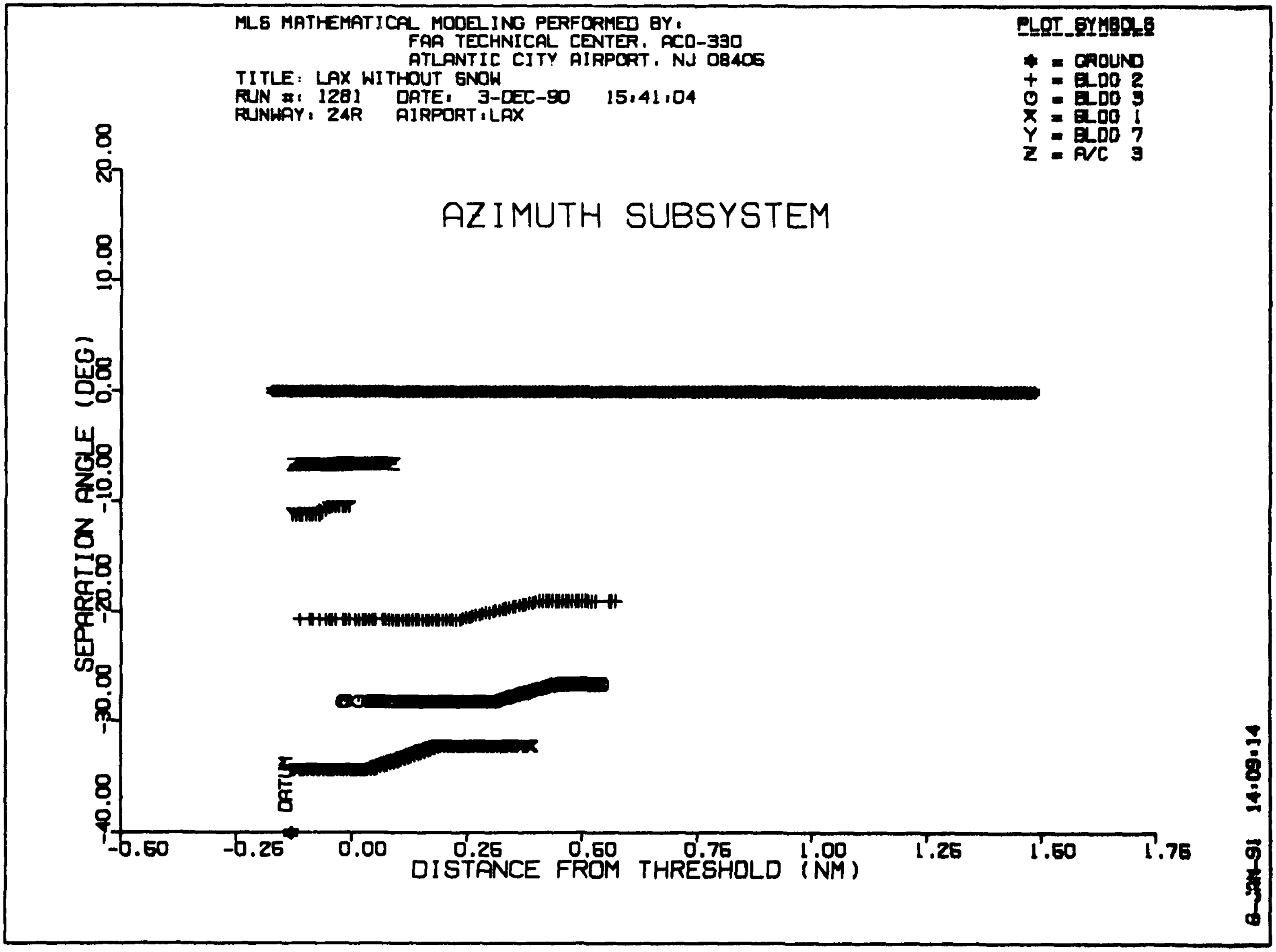

FIGURE A-6. AZIMUTH SUBSYSTEM - SEPARATION ANGLES

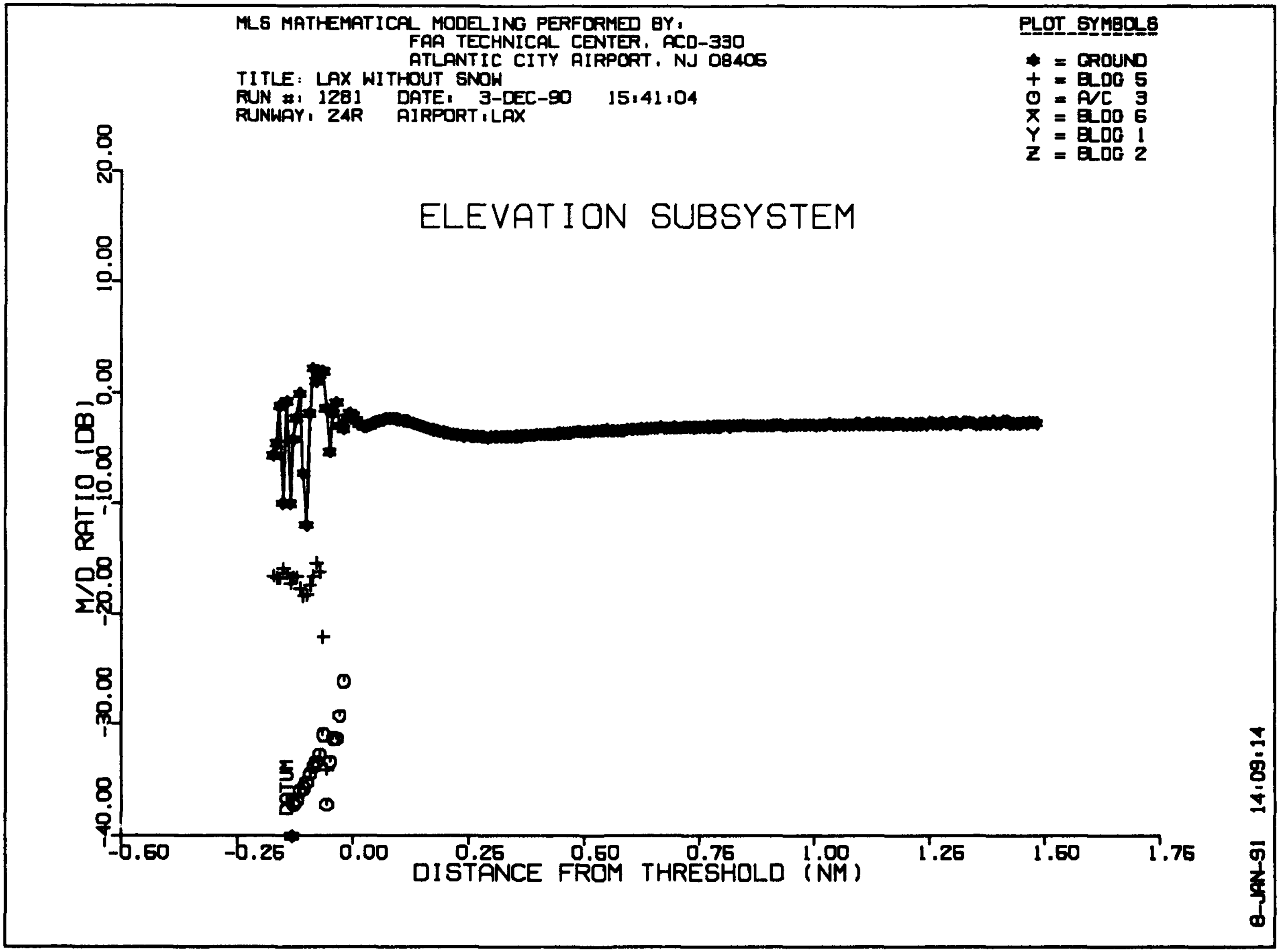

FIGURE A-7. ELEVATION SUBSYSTEM - MULTIPATH/DIRECT SIGNAL RATIOS

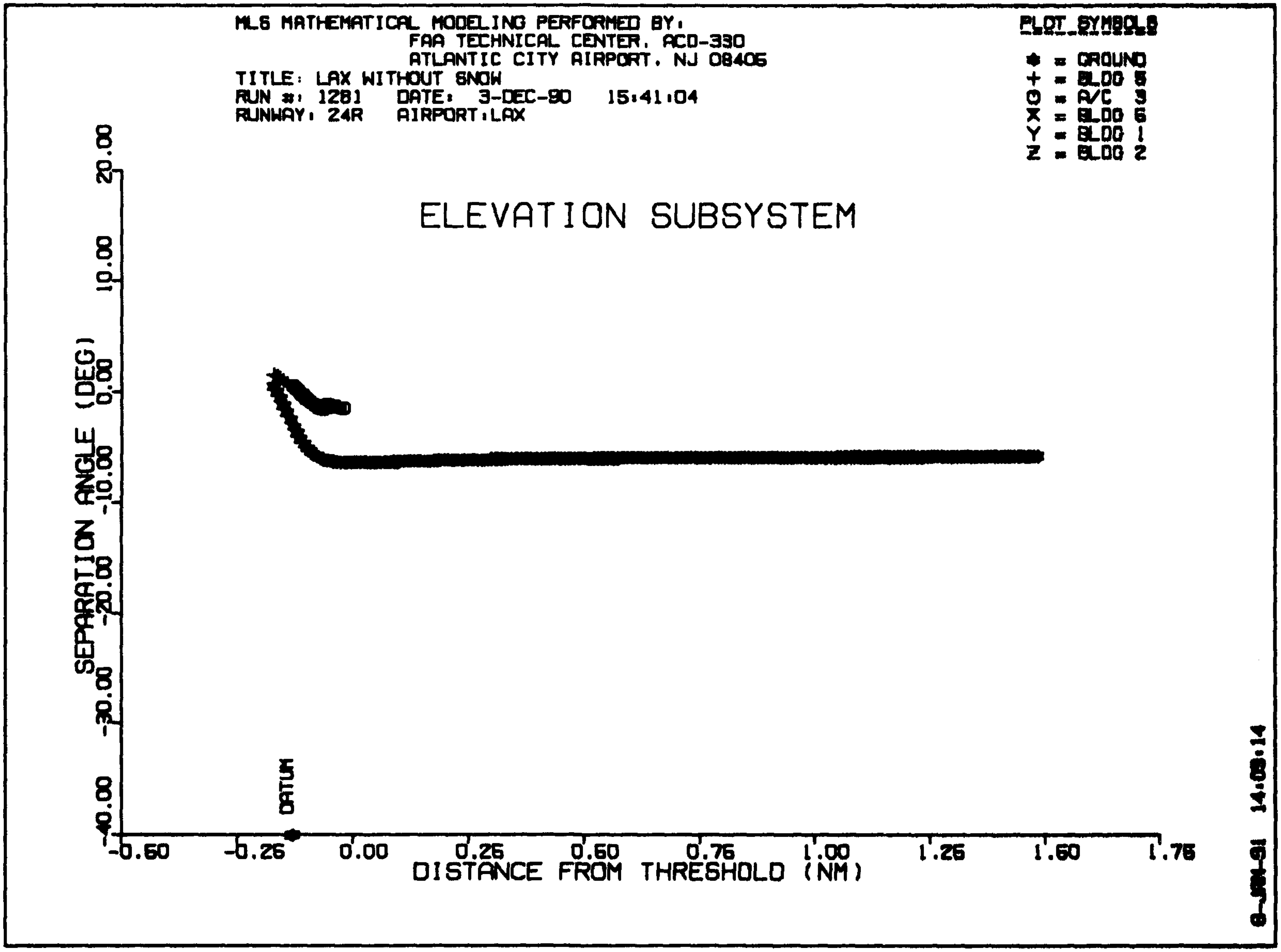

FIGURE A-8. ELEVATION SUBSYSTEM - SEPARATION ANGLES

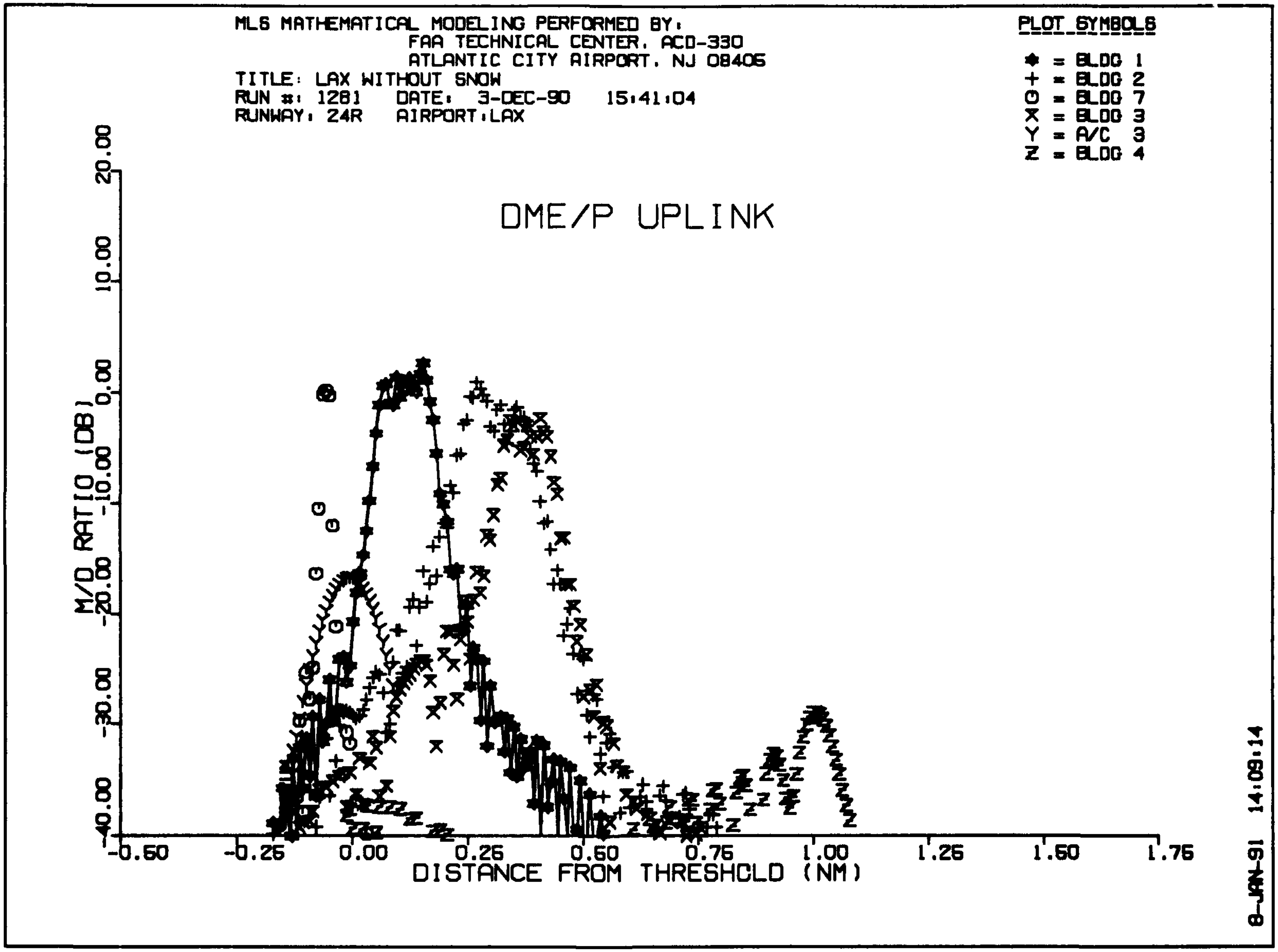

FIGURE A-9. DME/P UPLINK - MULTIPATH/DIRECT SIGNAL RATIOS

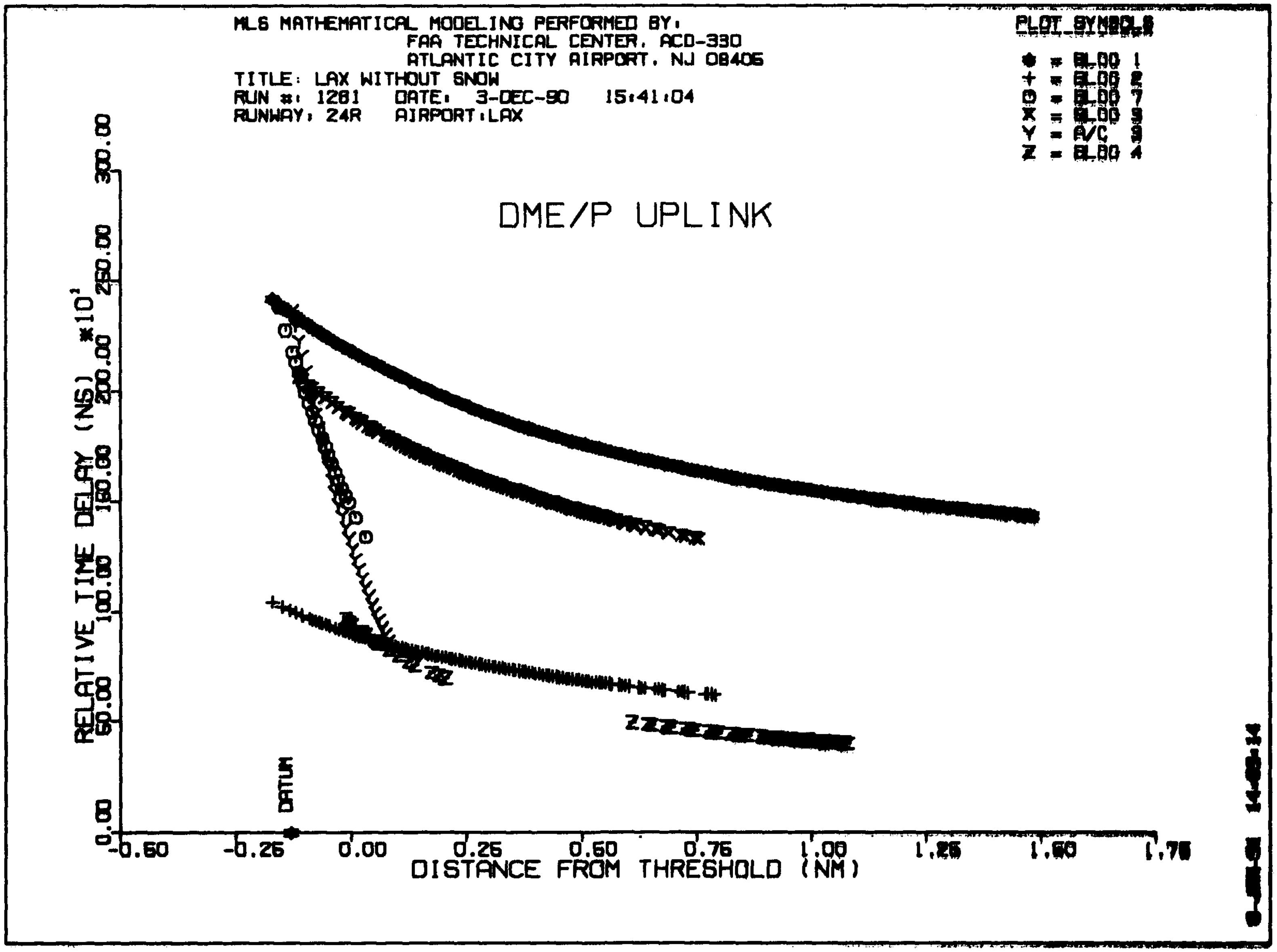

FIGURE A-10. DME/P UPLINK - RELATIVE TIME DELAYS

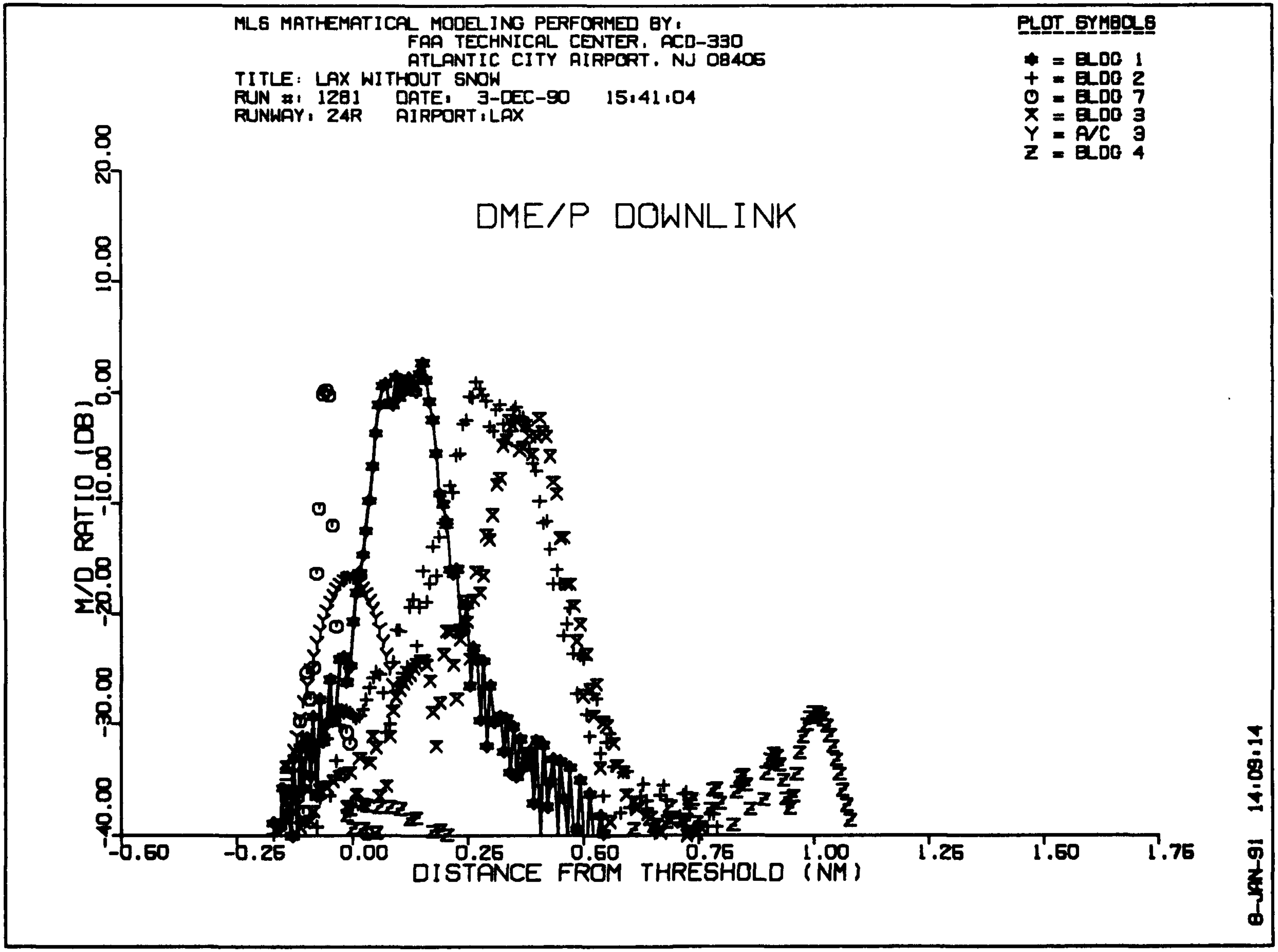

FIGURE A-11. DME/P DOWNLINK SUBSYSTEM - MULTIPATH/DIRECT SIGNAL RATIOS

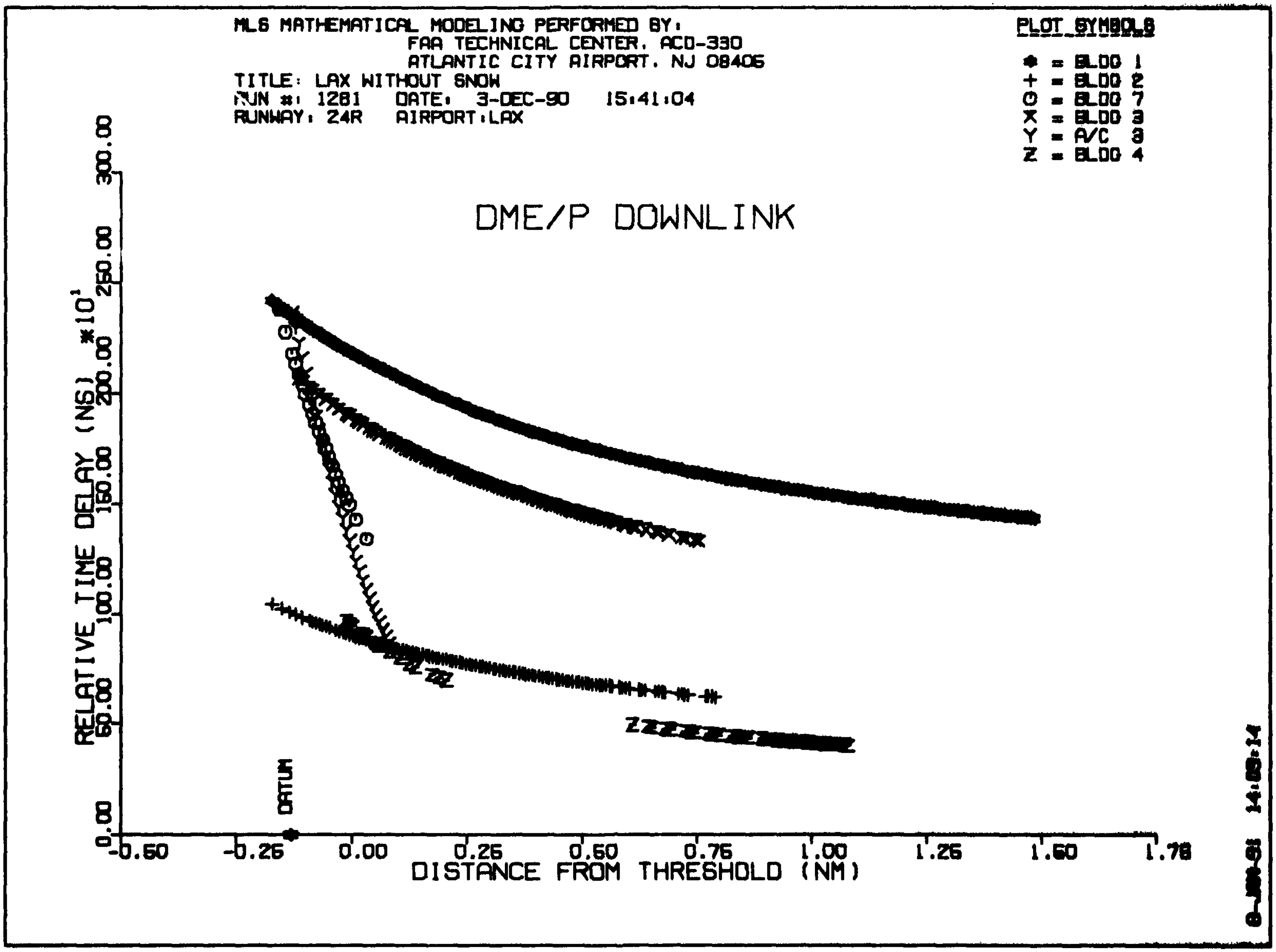

FIGURE A-12. DME/P DOWNLINK SUBSYSTEM - RELATIVE TIME DELAYS

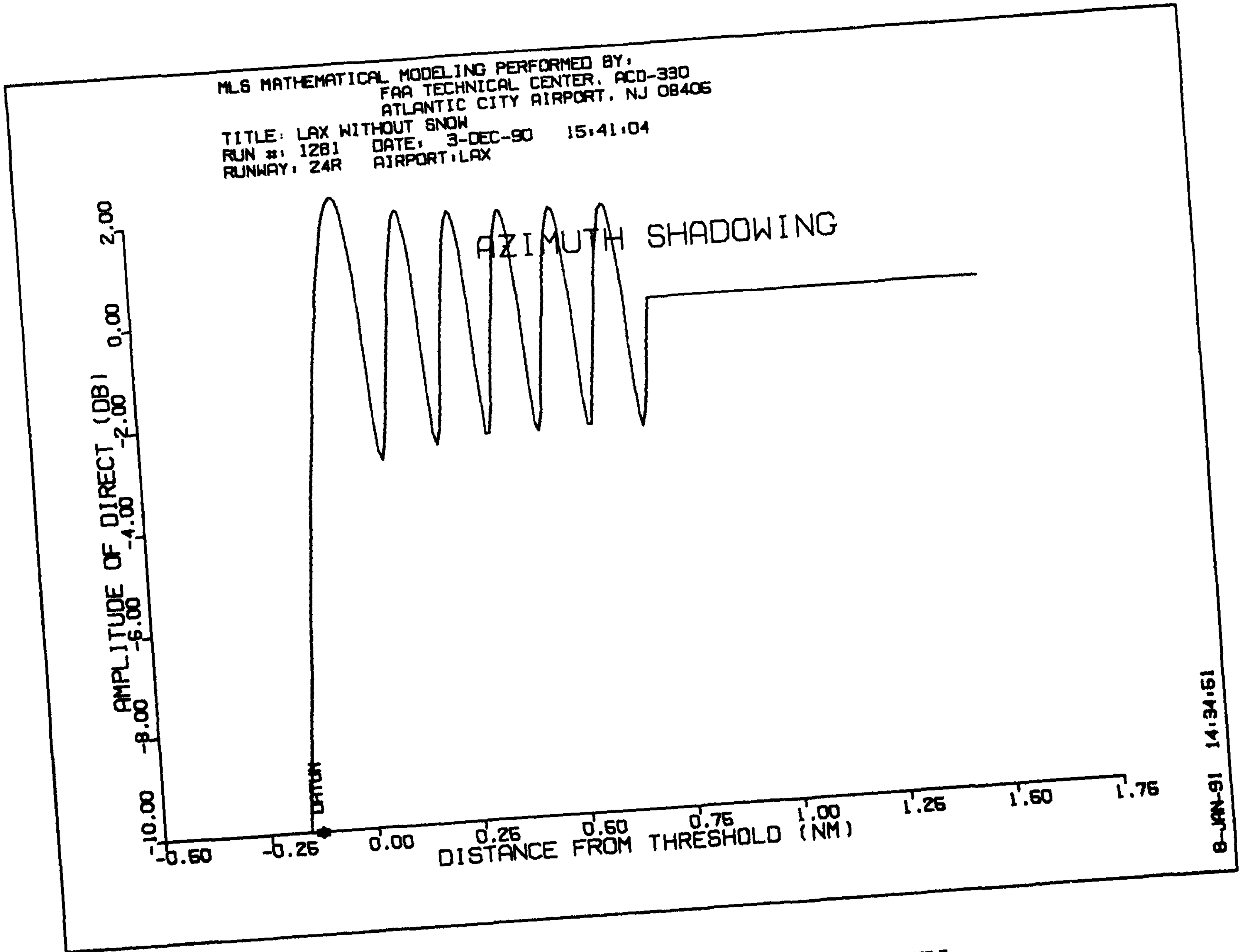

FIGURE A-13. SHADOWING OF AZIMUTH DIRECT SIGNAL

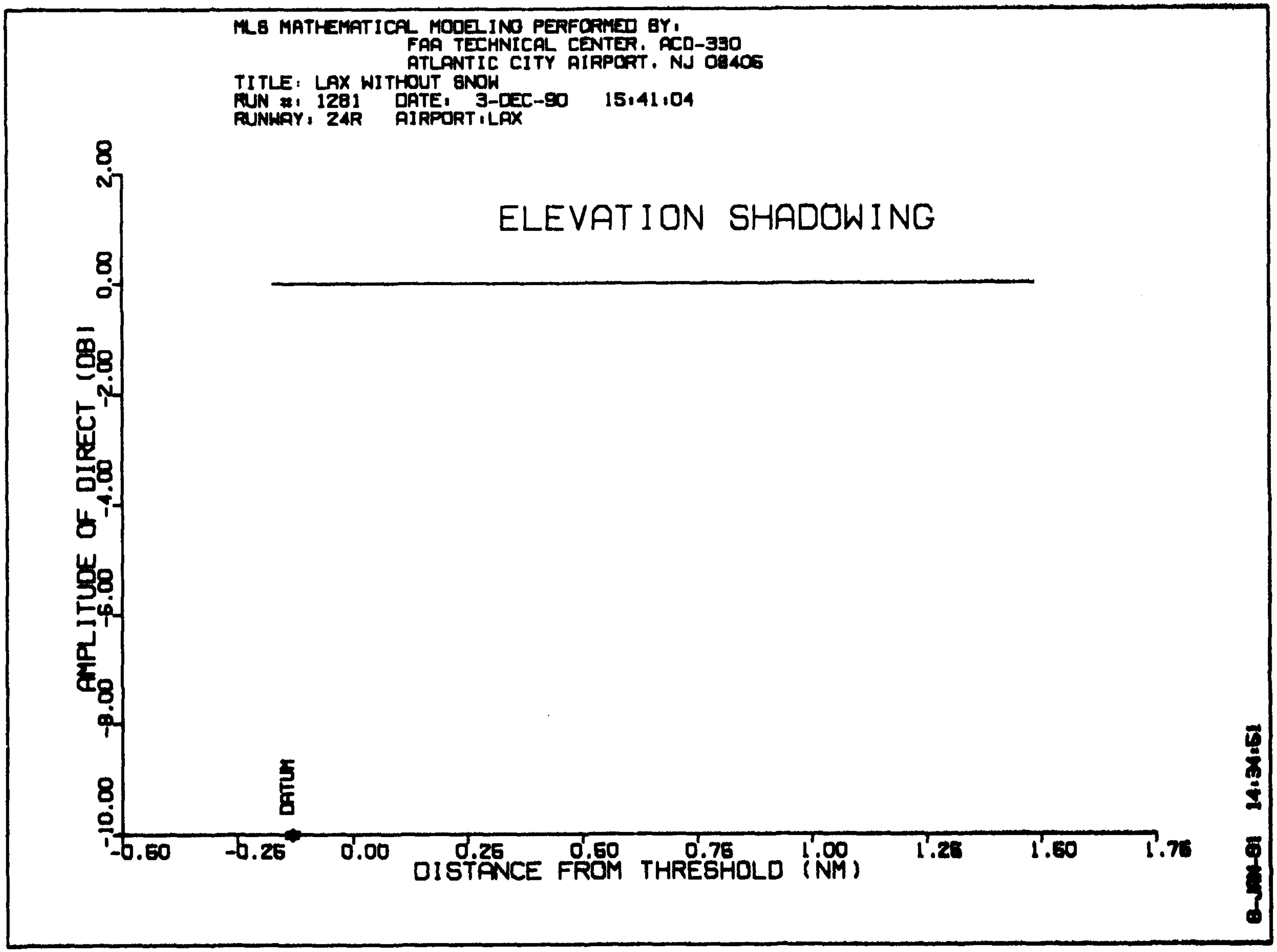

FIGURE A-14. SHADOWING OF ELEVATION DIRECT SIGNAL

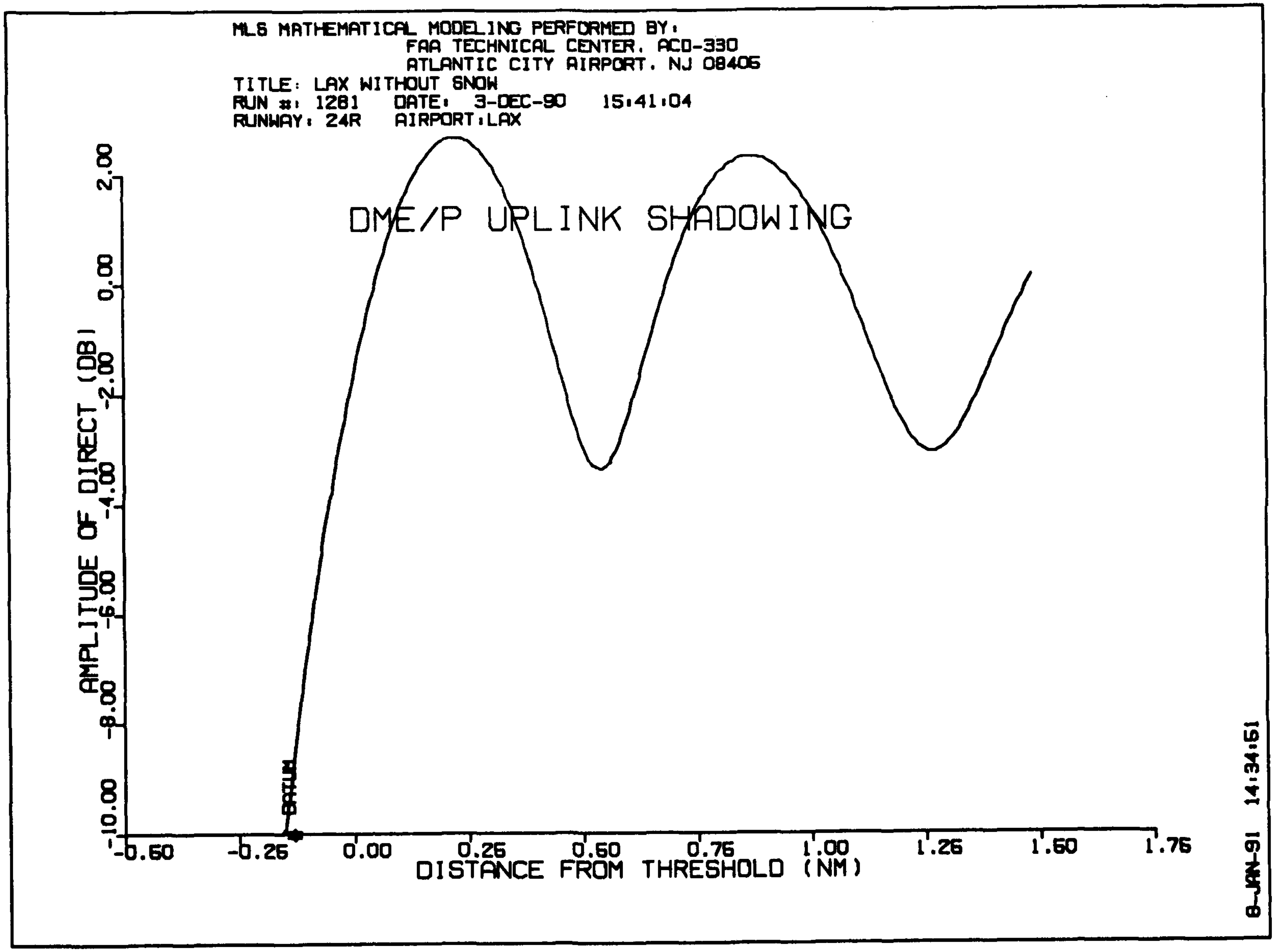

FIGURE A-15. SHADOWING OF DME/P UPLINK DIRECT SIGNAL

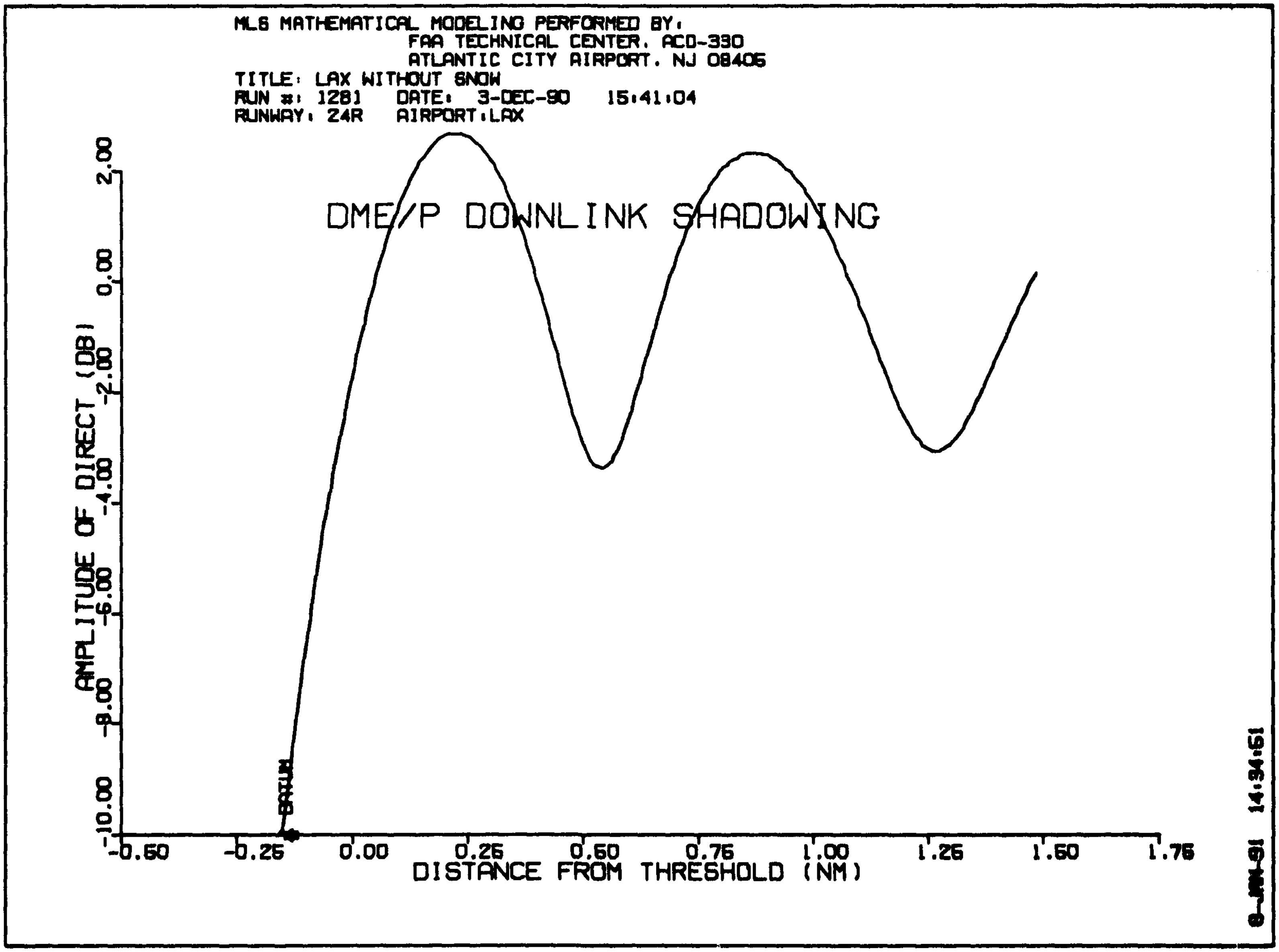

FIGURE A-16. SHADOWING OF DME/P DOWNLINK DIRECT SIGNAL

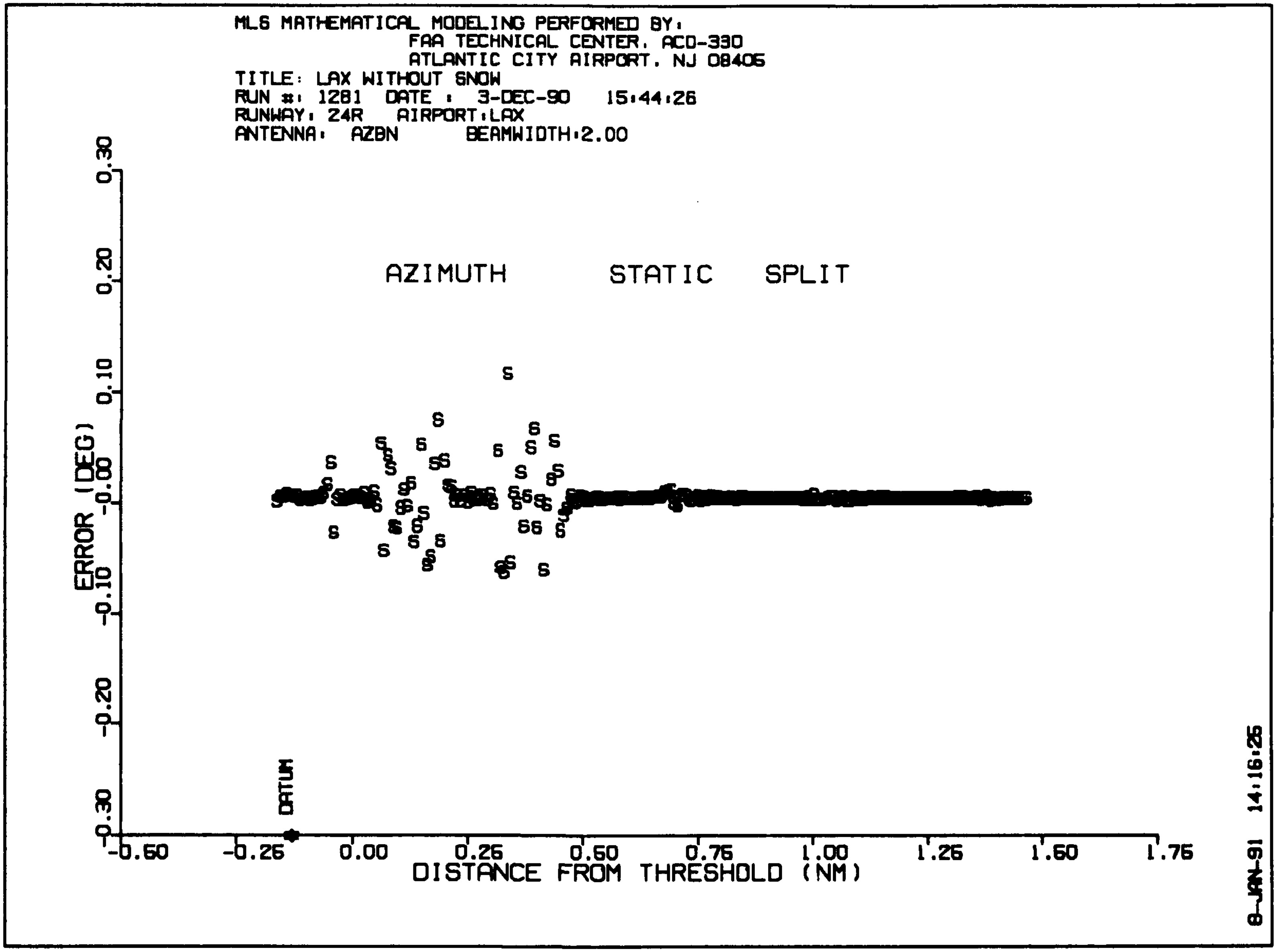

FIGURE A-17. AZIMUTH STATIC ERRORS

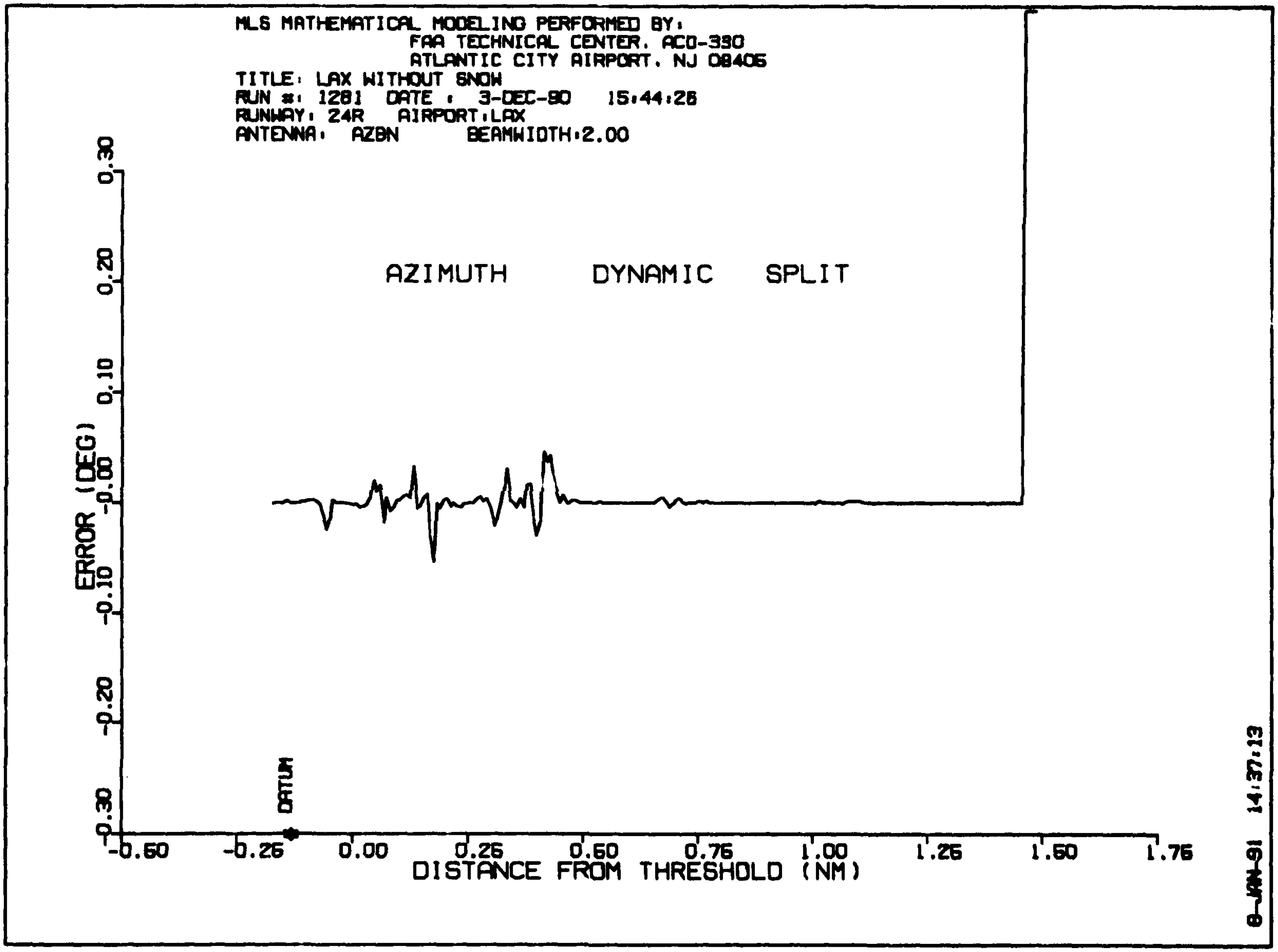

FIGURE A-18. AZIMUTH DYNAMIC ERRORS

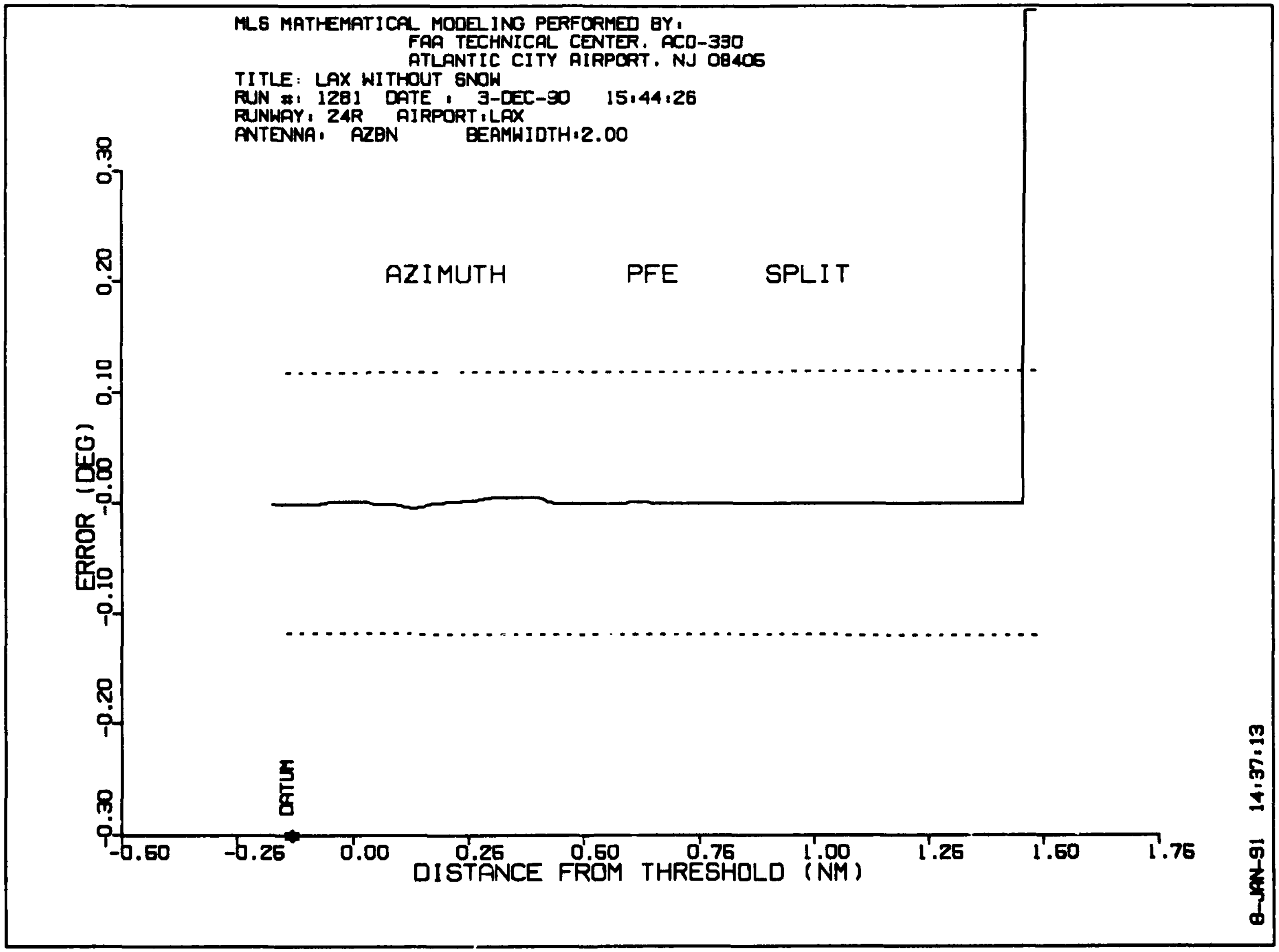

FIGURE A-19. AZIMUTH PFE ERRORS

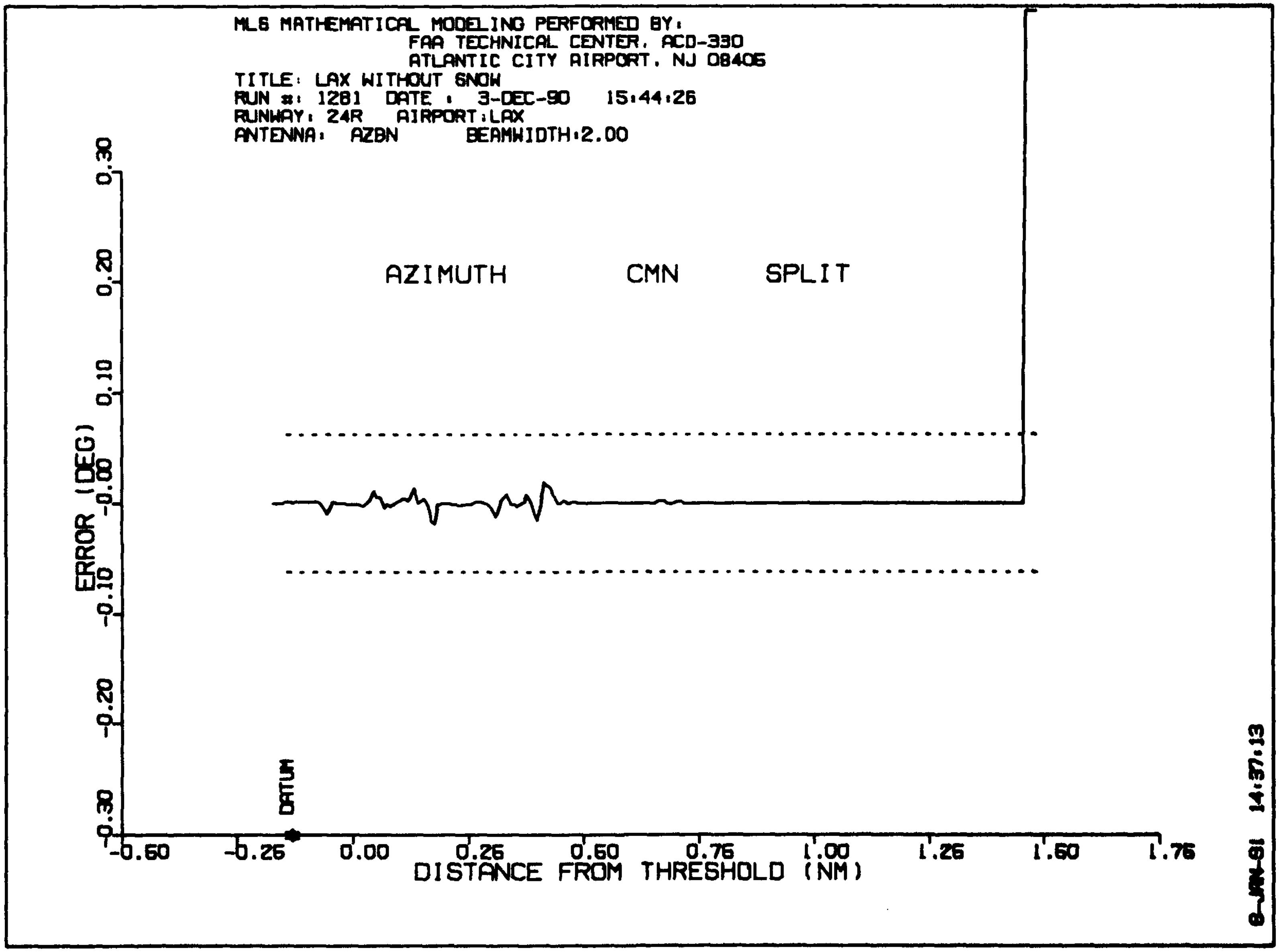

FIGURE A-20. AZIMUTH CMN ERRORS

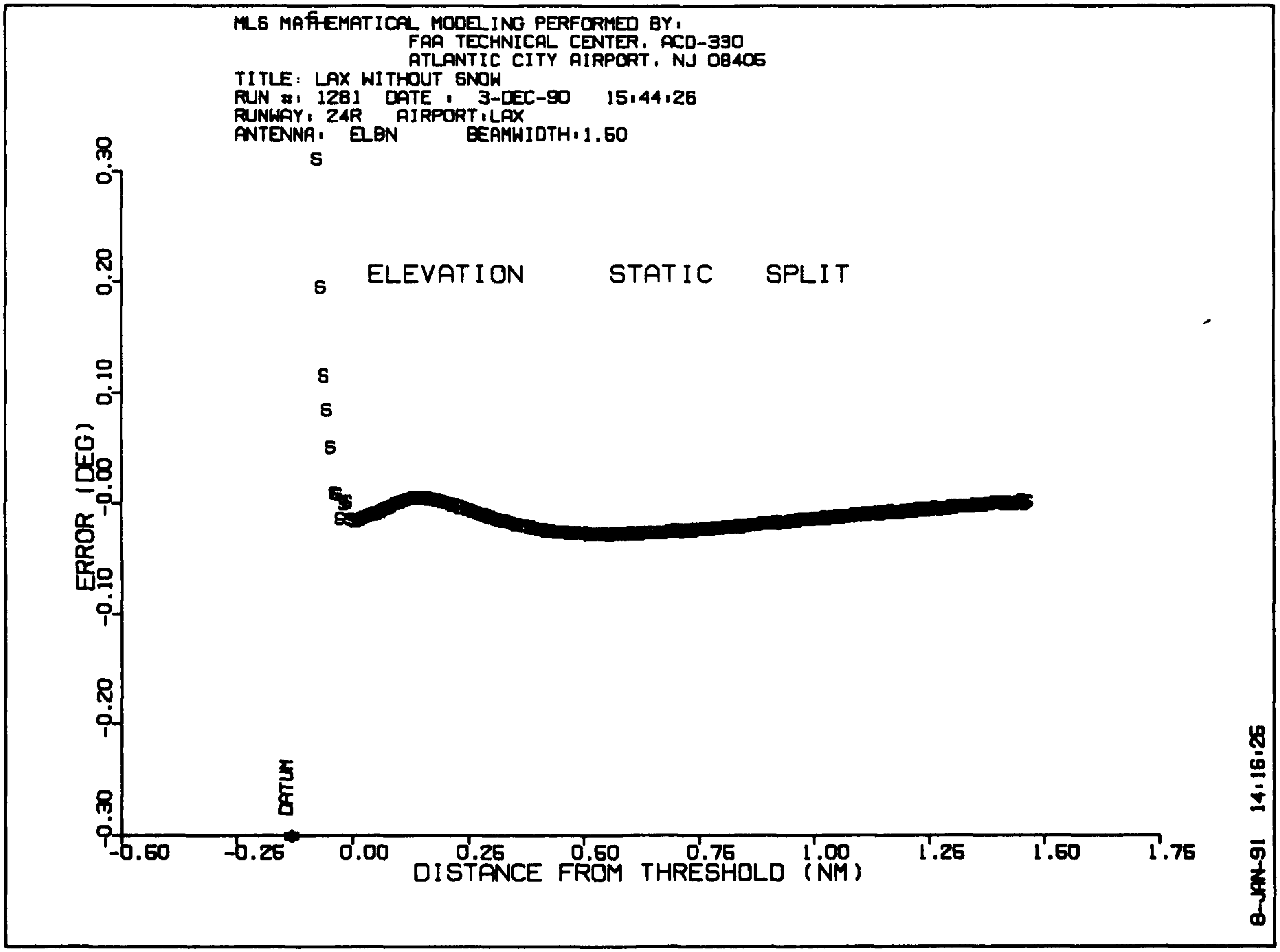

FIGURE A-21. ELEVATION STATIC ERRORS

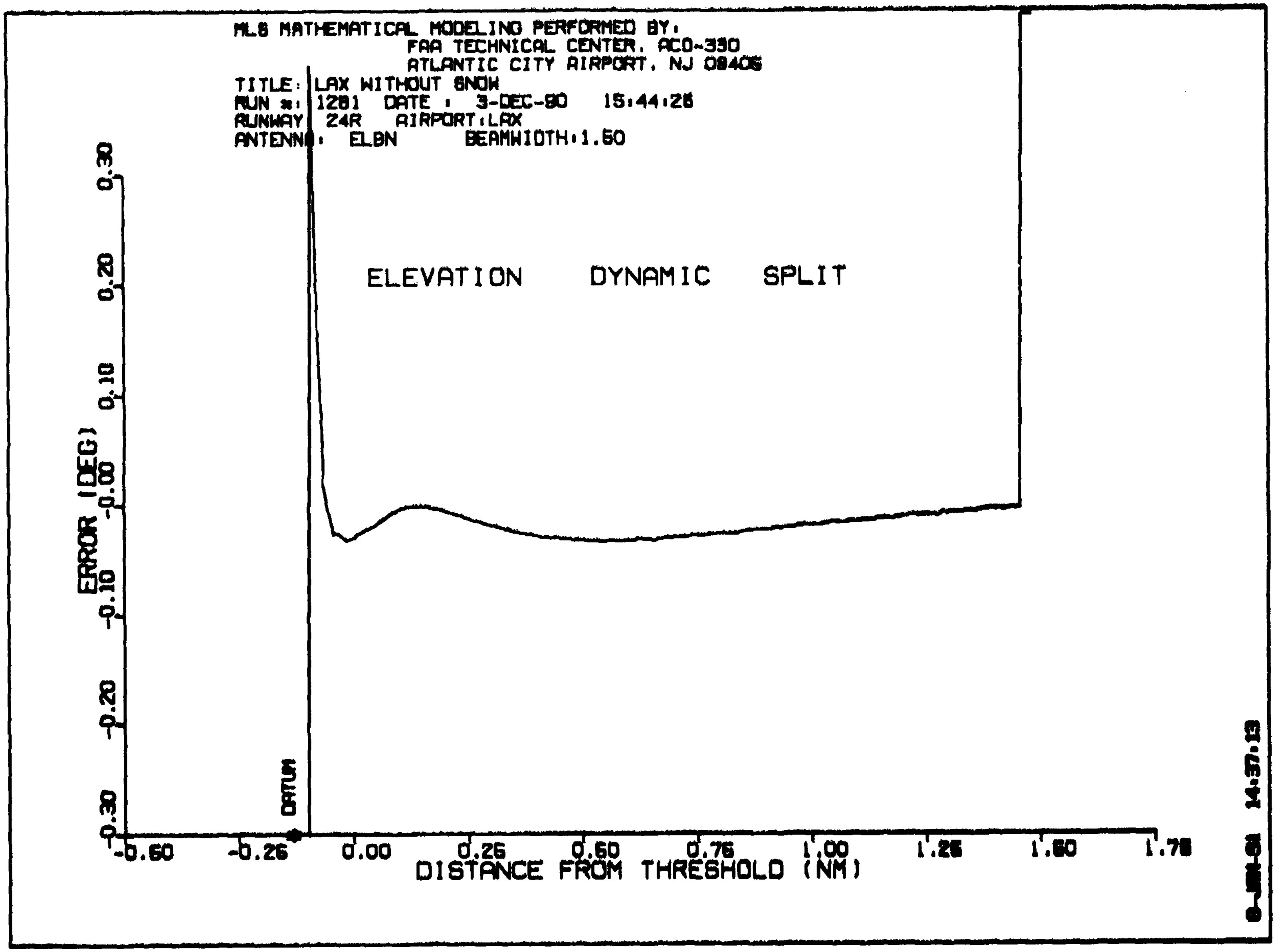

FIGURE A-22. ELEVATION DYNAMIC ERRORS

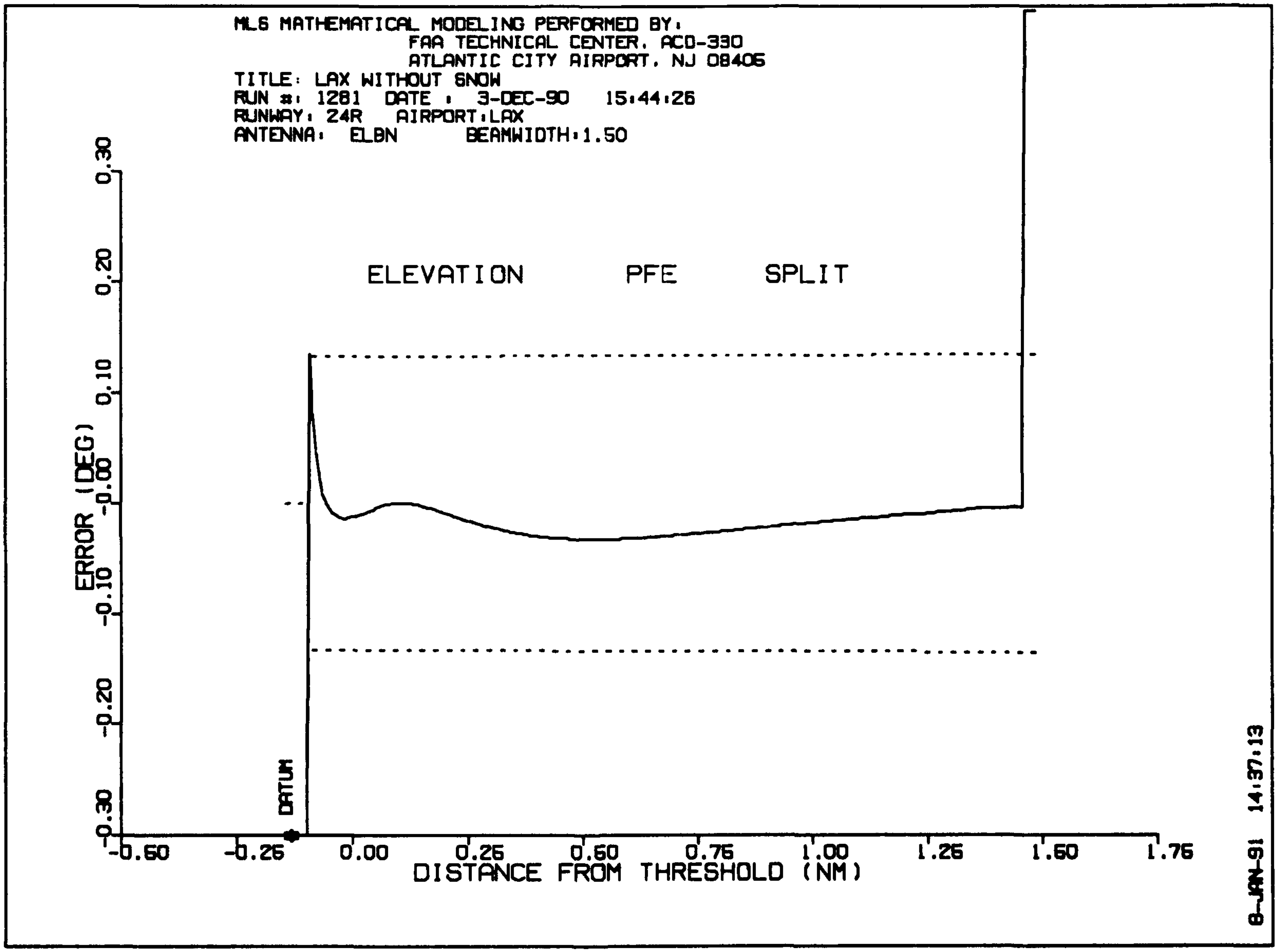

FIGURE A-23. ELEVATION PFE ERRORS

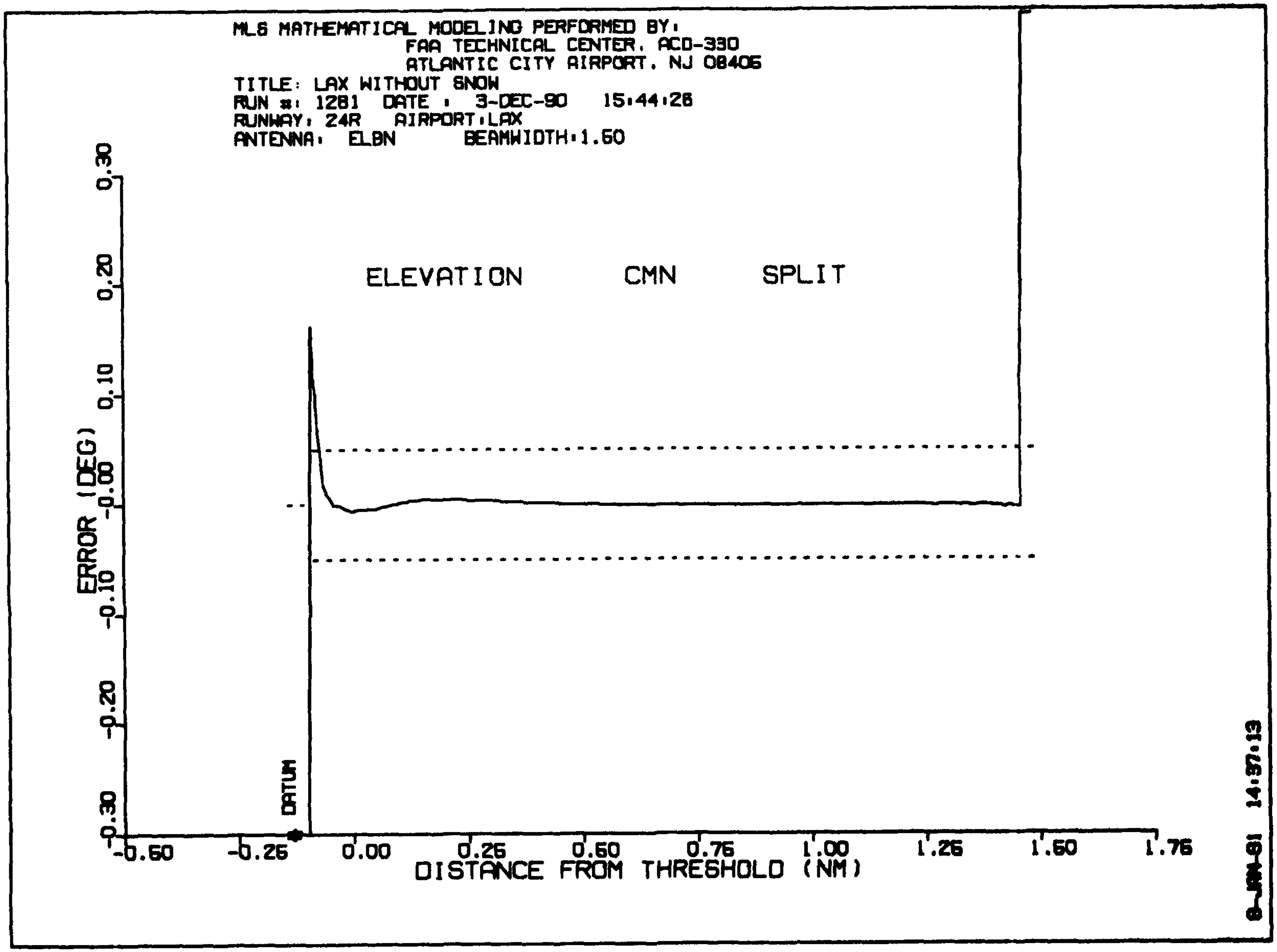

FIGURE A-24. ELEVATION CMN ERRORS

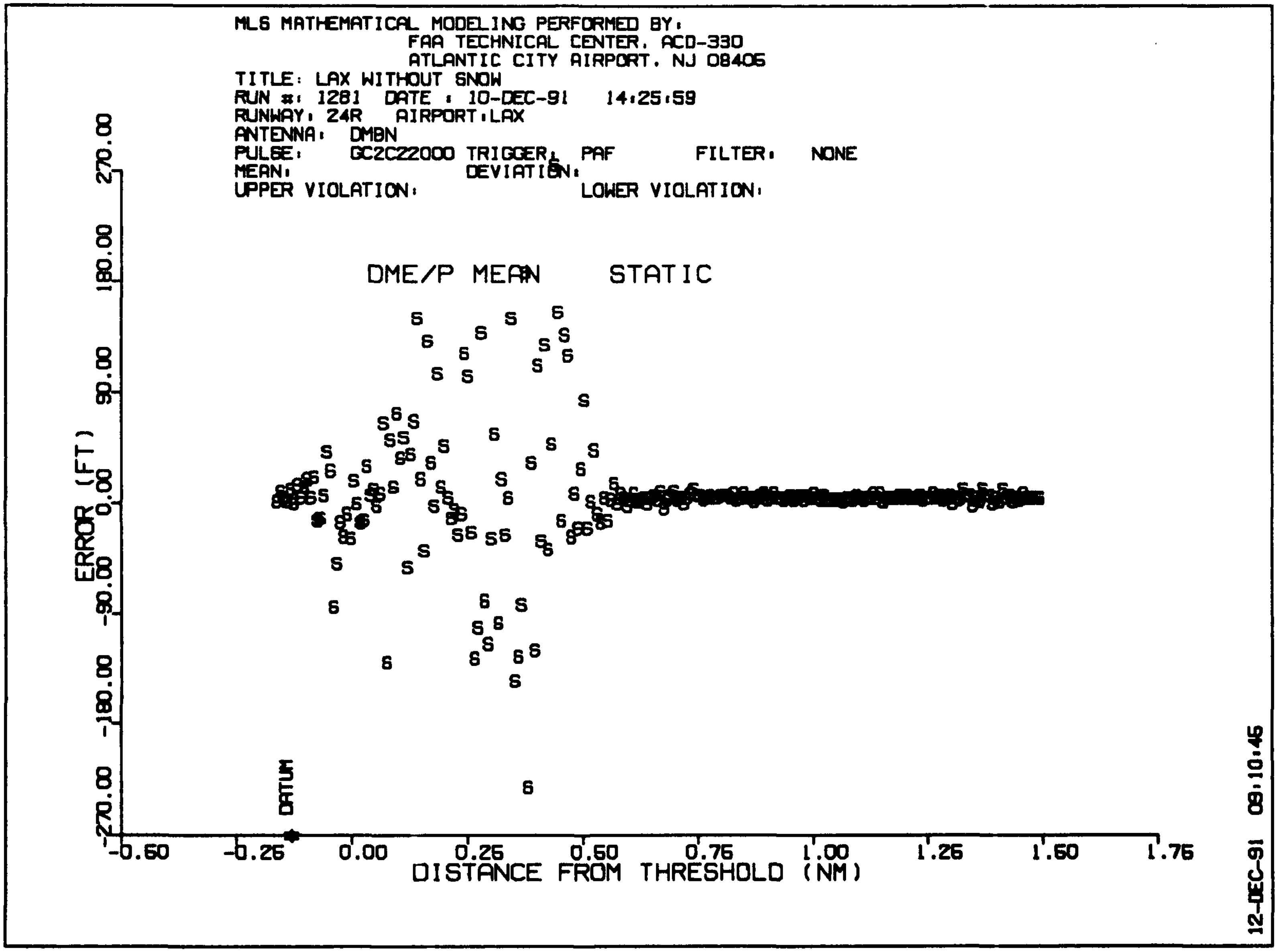

FIGURE A-25. DME/P MEAN STATIC ERRORS

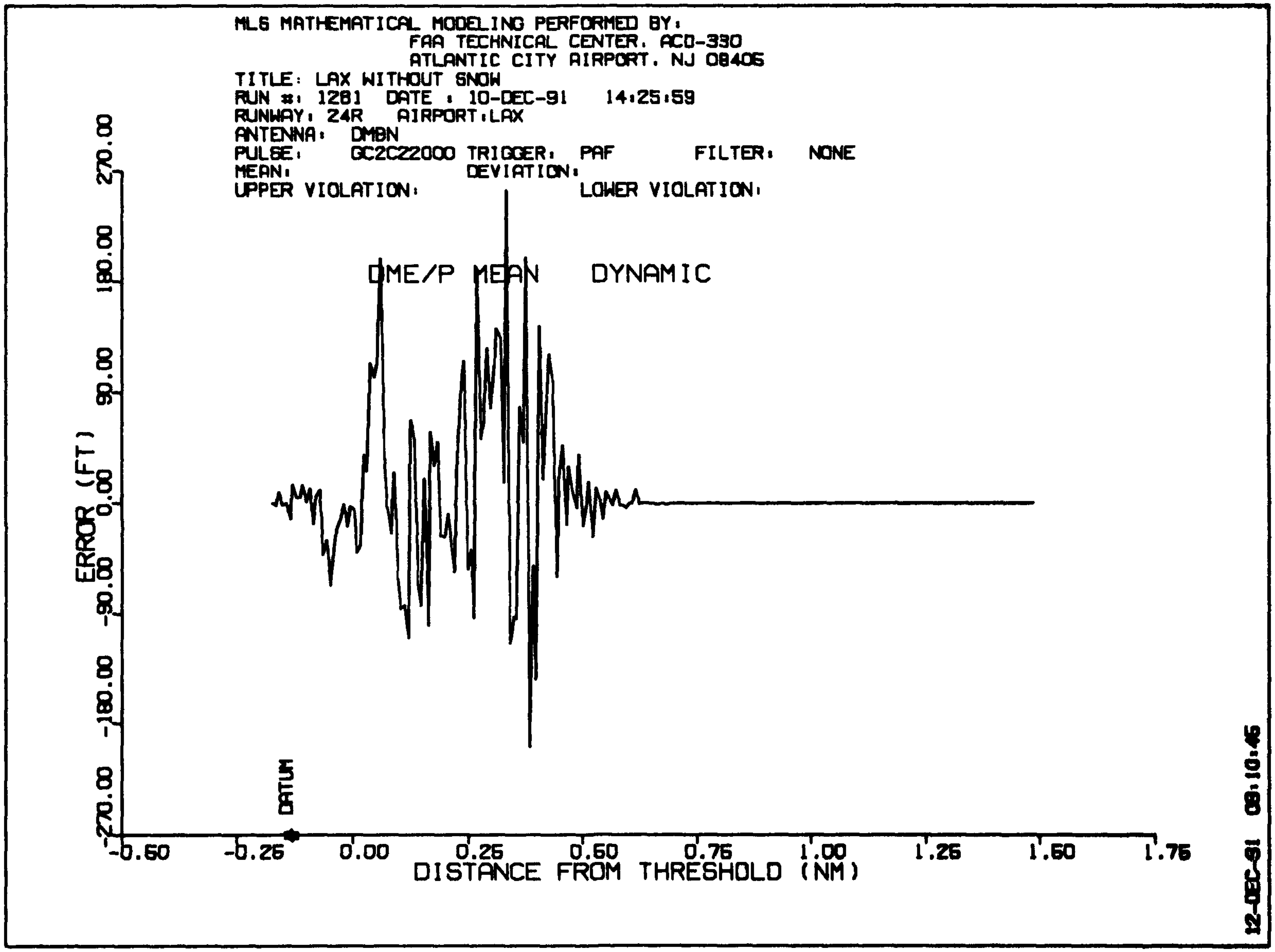

FIGURE A-26. DME/P MEAN DYNAMIC ERRORS

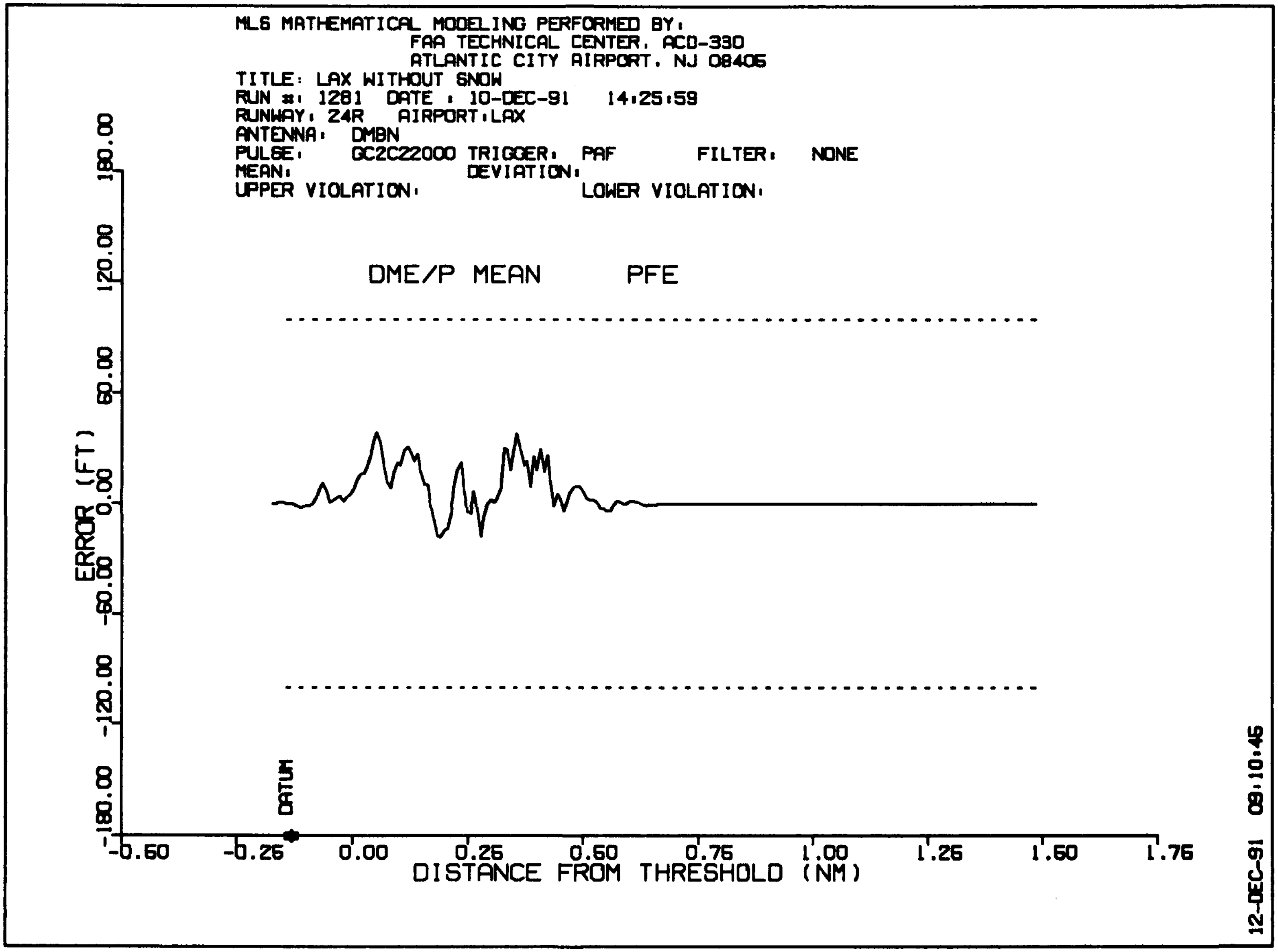

FIGURE A-27. DME/P MEAN PFE ERRORS

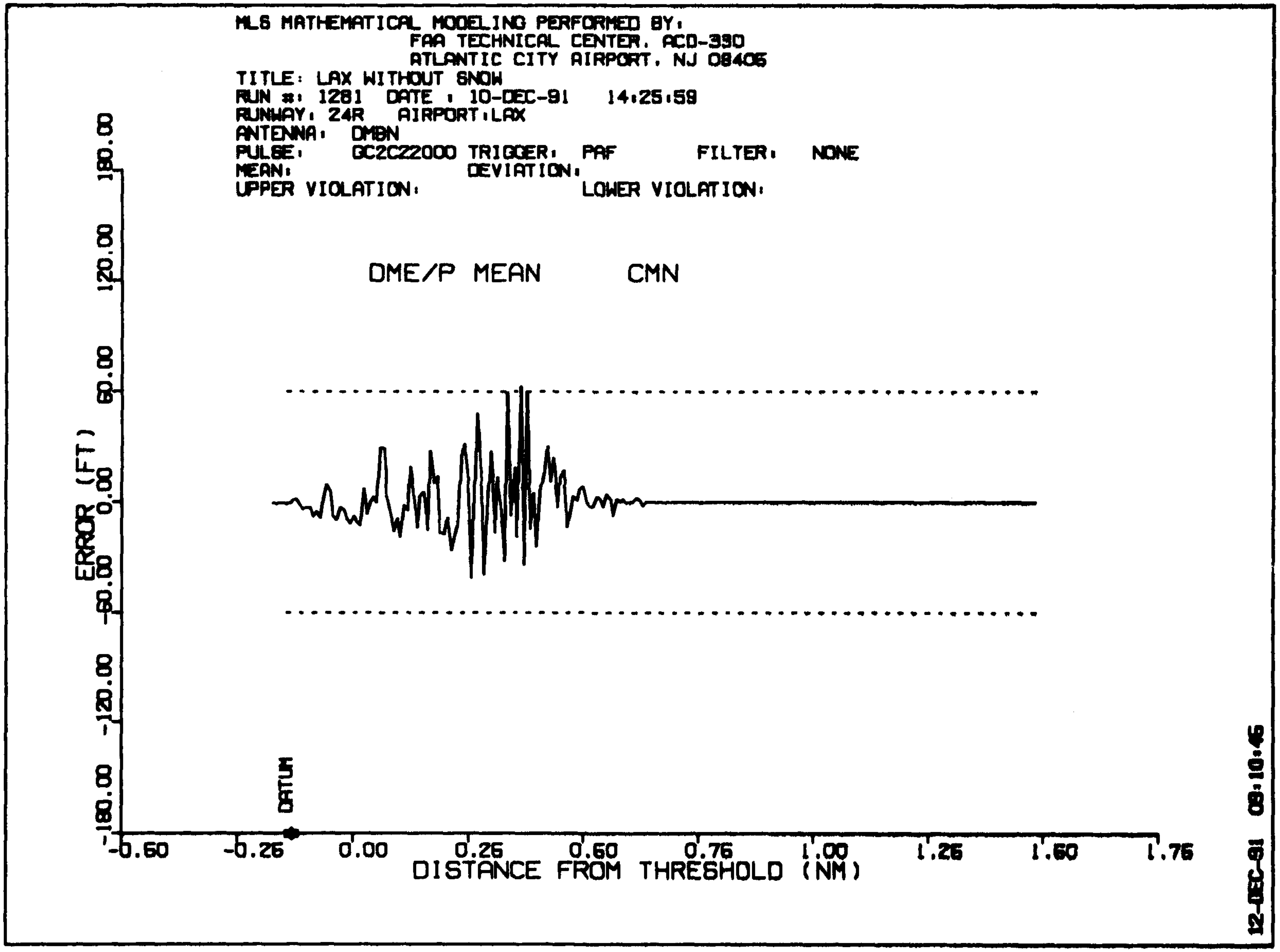

FIGURE A-28. DME/P MEAN CMN ERRORS

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